PROCEEDINGS

OF THE

MOBILITY RESEARCH CONFERENCE

Washington, D.C., September 25, 1961

Massachusettes Institute of Technology, October 11 - 13, 1961

James W. Linsner, Editor

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P R O C E E D I N G S

of the

M O B I L I T Y R E S E A R C H C O N F E R E N C E

Washington, D. C., September 25, 1961
Massachusetts Institute of Technology, October 11 - 13, 1961

Sponsored by: American Foundation for the Blind, Inc.
The Seeing Eye, Incorporated
Office of Vocational Rehabilitation (DHEW)
Veterans Administration

James W. Linsner, Editor

AMERICAN FOUNDATION FOR THE BLIND
15 WEST 16th STREET
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May, 1962
A M E R I C A N F O U N D A T I O N F O R T H E B L I N D
15 W E S T 16th S T R E E T N E W Y O R K 11, N. Y.

PREFACE

The publication of these proceedings represents the part-time efforts of one staff member and one secretary. Consequently certain anomalies and inconsistencies in orthography, punctuation, etc. could not be eliminated in a reasonable length of time. We have endeavored, however, to be faithful to the various authors' intents and beg their indulgence for these less important errors.

We wish to thank Mr. Louis Rives and Mr. C. W. Bledsoe of the Office of Vocational Rehabilitation for arranging the Washington conference, Dr. Eugene Murphy and Mr. Howard Freiberger of the Veterans Administration for helping arrange the Cambridge conference, and the Department of Electrical Engineering at M. I. T. for donating the facilities for the Cambridge conference.

We owe special debts of thanks to Mr. John Dupress for providing us with the minutes of the Washington conference, to Mr. Howard Freiberger for providing us a summary of those sessions of the Cambridge conference held in the Vannevar Bush Room at M. I. T., and to Miss Mildred Gold for her unflagging secretarial efforts.

James W. Linsner
May, 1962

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INTRODUCTION

by

John K. Dupress

These conferences were called to contribute to the following objectives:

1. To review and evaluate past and present mobility rehabilitation and research efforts

2. To establish communications between mobility rehabilitation specialists and scientists who are interested in sensory deprivation

3. To secure suggestions from mobility rehabilitation specialists for future research projects

4. To initiate and expand a long-range research program in the area of mobility for blind and deaf-blind persons

CONFERENCE OF MOBILITY REHABILITATION SPECIALISTS

Washington, D. C.
September 25, 1961

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MINUTES OF THE CONFERENCE
by John K. Dupress

Mr. Louis Rives, Chief, Division of Services for the Blind, Office of Vocational Rehabilitation, welcomed the group of rehabilitation specialists. He asked that participants put forward all the problems which they believe could be usefully researched. He expressed the hope that out of this conference and those to follow, there would come a research plan which would result in successful application of research. After these brief remarks, the meeting was turned over to the Chairman.

The Chairman briefly reviewed past and present research efforts in order that those in attendance might be brought up to date. Also some participants at the Washington Conference would not be able to attend the MIT meeting.

(For this review see p. 48ff., p. 61ff., p. 64ff. and p. 180ff.)

The Chairman pointed out that much of this research was only a beginning. For example, the early work of Dallenbach et al investigated obstacle sensing only in connection with hearing. They did not go on to explore all the parameters attendant on successful navigation. The use in mobility of sensory channels other than hearing has not been explored, nor has the question of navigation in general. (Many of these questions are raised in the first draft prospectus which is included at the end of these proceedings.)

The comment was made that we do not have any useful data on the mobility of deaf-blind persons with the exception of one project in which a few deaf-blind subjects were used by Dallenbach. Is it possible to bring those with impaired hearing (as opposed to totally deaf-blind) to useful mobility? Even though they may not be able to operate as efficiently as blind persons especially in unfamiliar territory, nevertheless this is a subject which should be investigated.

The Chairman mentioned one project not reported elsewhere in these proceedings, i.e. the project at The Cleveland Society for the Blind to determine the usefulness of hearing in mobility and to increase the individual's ability to use his hearing. This project resulted in certain tests and binaural training tapes.

(See general reference # 6.)

The Chairman pointed out a lack of research in the following areas: a) the validation of tests used at rehabilitation centers; b) the relative usefulness of various parts of the rehabilitation program; c) an objective scale for rating a client's progress; d) the follow-through, i.e. the effectiveness of rehabilitation over a period of time; e) the specific problems of the aging traveler; f) the need for mobility by the elderly blind. This is a pertinent question, since most rehabilitation is oriented toward those who have vocational capabilities.

There is a general lack of data on: 1) the need for mobility among various parts of our population; 2) the correlation of mobility capability with vocational placement; and 3) comparisons of the need for mobility training in urban and rural areas. The lack of statistics and other information on the need for mobility capability makes it difficult to tell technologists, psychoacoustics researchers and others, what market their products will find.

The Chairman asserted that the lack of success in instrumentation research is due to: a) a lack of information on how the individual sees; we cannot extract information from the visual field in a way that is meaningful, and b) insufficient study of the natural capabilities of man; we are not in a position to supplement his capabilities successfully until we know more about them.

Another question is, What happens in the visual centers of the brain when they are not processing? To what use might they be put? If we knew what these brain areas were doing, we would be in a better position to determine what the limits of the individual are, and we could estimate what we might expect to feed into other sensory channels. Some fruitful research has been undertaken in the sociological and psychological fields, e.g. studies of the attitudes of blind and sighted people towards mobility, and the adjustment of blind persons (See p. 76 ff.) These attitude and adjustment studies must be continued and expanded.

Mr. Bledsoe:

"In view of what you have just said, I would like to read a quotation from Dr. Hoover at the Miami meeting of AAWB. He was saying that he had talked to them before about mobility, and he says:

'I refer again to 1947.... I stated at that time there was nothing mysterious, nothing complicated about most systems of foot travel. It is nothing more than a combination of hard, cold practical logic and elementary physical, physiological and psychological facts and principles based on some very amateurish experimentation, observation and discussion. Here I would like to pass out a warning. While I say it is not terrifically complicated, there is nothing certainly mysterious about it, it is yet something that people should not be expected to learn in ten easy lessons. I like to compare it to that very simple, and to some the very silly little game of golf. The game is not mysterious nor is it complicated. All you have to do is take a little iron or wooden rod about the length of a cane, and swat a corrugated little hard ball along a very beautifully designed, prepared and kept course, and all you have to do is 75 or under to be with everybody else.'

It seems to me that what we are trying to do here is reconcile this point of view with the fact that we have a tremendously large basic and applied research program at M. I. T. directed toward the same ends, and I personally do not think that the two points of view are as unreconcilable as they might seem at first glance."

Mr. Bledsoe went on to say that the purpose of these meetings is to reconcile the two points of view, that of research and rehabilitation, and that they are not really any great distance apart.

The Chairman said the reason why he attempted to stimulate a broad research program at MIT is that in this area of New England there is a concentration of technical, social science and medical research facilities. Furthermore, one of the major rehabilitation centers, St. Paul's, is nearby. He said he does not believe that researchers think of their research as a substitute for mobility capability or for rehabilitation programs. Instead, basic research attempts to measure the capabilities of the human, and instrumentation should be designed to supplement the trained capabilities of the human. The Chairman concluded by saying he thinks the real problem has been a lack of communication between researchers and rehabilitation specialists.

A question was raised concerning the permutations and combinations in obstacle sensing. The chairman referred to an article written by Dr. Wright and Mr. Dupress in the Shilling report. He said there were a large number of variables operating. For example, the subject may be stationary or moving; one or more objects in the surround may be stationary or moving and may be sounding or silent. The building line he is tracking may itself produce sound and also serves as a reflecting surface for sound. There is a great deal of ambient noise in the atmosphere. It is possible sometimes to detect an object which presents an auditory shadow in this ambient noise field. There are, in other words, many variables constantly changing, thereby making obstacle sensing possible but in many cases extremely difficult. The successful blind traveler learns to interpret this array of sounds. In conclusion there are conditions in which the ambient sound levels are so high that very little useful information is obtained from the auditory environment. Therefore, the blind traveler must depend upon his remaining sensory channels and his knowledge of the environment to see him through.

The Chairman pointed out that much of the success of mobility training programs depends on the individual instructor. It may not be possible to secure enough competent mobility specialists to train all those blind people who wish to be mobile. It is too much to expect that every mobility rehabilitation specialist be of the same high caliber of those present. The alternative is to find how some of the procedures can be standardized, leading to higher and more uniform level of training. There is a gradual and subtle deterioration in the remaining sensory channels, particularly hearing, as people grow older. This needs to be studied in its effect upon maintaining an acceptable level of mobility capability.

Mr. Bledsoe then quoted from what a rehabilitation specialist has said:

Mr. Bledsoe:

> " 'If you are going to teach a person who cannot see to travel on foot, you must think constantly of hearing, touch, sense, muscular sensation and obstacle sensation as aids for the blind man in getting around. Only in this way can you discover what sounds, sense and obstacles mean to people who cannot see just as only by thinking in a foreign language can you master it. You must apply the blind man aids wherever you go. You must listen for sounds such as the noise of a heat pipe which could be an aid for a person without sight. You must be alert for smells such as that of a bakery or drugstore. You must notice the quality of the terrain under foot with your own shoes. In order to know the skill of foot travel without sight you must blindfold yourself and experiment in performance as much as possible. Even if you do this a great deal, you probably will not develop your senses as acutely as a blind man does. Circumstances will not be sufficiently compelling because you know you will be able to see when you take your blindfold off. To make up for the understanding you lack because of this, you have to use your eyes constantly in an environment in which you teach in order to find objects which may furnish aid. You must get in the habit wherever you see some objects of asking yourself these questions: Does it make a noise, does it smell, is it hot or cold, and so forth'.

This is dated 1947 and there has been a great deal of practical work done since then by the people in this room. And the point is how to decide which of this is subject to scientific measurement and which is not. Where does art end and science begin? This is what we are trying to find out. I know that there are people here who can certainly call their shots in teaching foot travel and when you started talking about these obstacles and measuring what they are, it suddenly occurred to me that mere observation may be way out ahead. And I'm sure that everyone here is wondering about this."

Mr. Richterman wondered if such things as the effects of family relationships, racial background, previous occupation, intelligence, etc., admitted of useful scientific inquiry.

The Chairman said that social science researchers should be capable of finding out how some of these factors are related to one another and how they affect the training of the blind person. The results of such research must be interpreted, however, to the rehabilitation specialists so that they can successfully use it.

The Chairman pointed out that it is necessary to get feedback of comment on the progress reports of research projects. This is necessary so that the research can be more meaningful. The Chairman said that he regretted the lack of feedback on the progress reports of the Shilling Project. The people in rehabilitation cannot expect us to benefit from their experience and knowledge unless they are willing to communicate to us their thoughts while the research is ongoing.

Mr. Richterman then said that some of the tests and materials arrived at during research do not seem to work out in practice. For example, a blind person can listen to special tapes in a sound room and become very competent at picking out all kinds of special sounds. When he goes out on the street however, this previous auditory training does not seem very useful to him. He postulated that perhaps the one additional factor which changes the situation is the fear of actually being hurt. He said unless improved training materials come out of research, he believes it is much better to have the individual out in the street hearing the air brakes on a bus rather than listening to them in a laboratory.

Mr. Bledsoe asked if there was any objection to giving the individual both. Mr. Richterman answered that he has no objection to this.

Mr. Bledsoe warned against the exception. He said that Dr. Hoover pointed out that people have much more in common in terms of mobility capability than they have differences. It follows, therefore, that one should not judge these tapes on the basis of one or two individuals or on the basis of one or two special conditions. It may be necessary to present these tapes to dozens or even hundreds of persons before the real value of such special training materials is known. Mr. Bledsoe suggested that some blind persons may be competent in both situations. Mr. Richterman said he is not nearly as much concerned with the person who does well in a test room as the person who does not do well there, since this may indicate some hearing impairment or inability to process the auditory information.

The Chairman said that perhaps research in the next few years may not result in large improvements in the person's individual performance, but rather in pin-pointing their difficulties. This would enable the staff to emphasize the appropriate parts of the program from the beginning. The real difficulties may be due to sensory or psychiatric factors, rather than simple lack of motivation, family objections, etc.

Mr. Werntz said that the previous discussion seemed to indicate that we ought to set up the equivalent of a public school program in which everyone would learn to travel. If we find anyone who isn't capable of traveling we could relax the regime until we arrive at a low enough level of capability that everyone can succeed. He wonders, therefore, if we should not make a study of the factors which cause blind people to want to move. The Chairman asked those present if they knew the factors in getting persons to mobility rehabilitation. Clearly there are no legal requirements as there are in the matter of school attendance. Mr. Rives stated that in the rehabilitation process the principle factor may not be that the individual himself wishes to apply, but rather that he needs vocational training. When he applies for vocational rehabilitation, the usefulness of mobility training is pointed out to him.

The question was raised concerning the percentage of blind persons who receive mobility training as opposed to those who travel but who receive no formal training. The Chairman said that he did not believe there was any accurate estimate of this.

Mr. Werntz said that in the New York School for Social Work Study three-fourths of the persons approached said they had not undertaken any kind of formal mobility training.

The Chairman asked if there were any concepts agreed to by a majority of mobility specialists concerning what level of capability should be reached by individuals.

Mr. Werntz said that probably it is the individual himself who should determine this. He knows both his needs, and his other handicaps which may limit his achievement. A variety of factors prevent everyone from achieving the same level of capability. Within certain limits of time, budget,staff, etc., the individual should be trained as far as his inherent capabilities will permit.

The Chairman asked how one determines that a person has changed from not being mobile to being mobile. Mr. Werntz answered that this is generally judged at the end of each phase of his mobility training. You evaluate his ability to cope with conditions at the end of each phase. The evaluation is one of performance. Care should be taken not to set a low standard so that the individual would not be secure when he has to perform in dangerous areas in a real situation. The trainee should not be over-protected.

Mr. Williams said that people come into his program at the age of 30 who have never progressed beyond traveling indoors. He also found men 65 years old and over who could travel through the most congested areas in Chicago. The pace at which individuals can be trained varies greatly from one individual to another. The ability to use sensory cues varies markedly from person to person. The person who seems able to go only up to the point where he is capable of traveling indoors is incapable of handling more complex and dangerous situations. The mobility trainer must determine this from how the individual deals with specific situations.

Mr. Rives asked how the specialist decides. Mr. Williams answered that he decides primarily on the basis of experience. Mr. Rives stressed that you had to have some measure of the individual's performance level in order to know where to place him for vocational purposes. Mr. Williams stated that where people have sensory or other limitations it is up to the mobility rehabilitation people to confront him with situations which will enable him to decide for himself what situations he can realistically cope with. In other words, they must help educate him so that he comes to a reasonable conclusion regarding his capacities. In other words, the level to which a person can expect to go must be arrived at by demonstration procedure Mr. Williams said there was a considerable amount of information on some 600 men collected at the Hines Rehabilitation Center. A useful research project might be to study the data at Hines and other rehabilitation centers in order to arrive at some guide lines for determining standards of performance.

Examples of general levels were given. One is the individual's ability to get around in a familiar environment. The second was listed as the individual's ability to travel in an unfamiliar environment. When there was no consensus as to whether it would be useful to set up specific guide lines to judge a person's performance, the Chairman asked if there was not an information exchange among rehabilitation centers that resulted in a tendency toward standardization. The answer given was that there is no systematic exchange of information.

The Chairman then asked if it might not be a good idea to gather data from each rehabilitation center and sort it for the common factors. Mr. Richterman answered that the kind of data the chairman is talking about is the very same data rehabilitation specialists have trouble with. How is he to decide what a given individual can do with a variety of complex factors to consider? Decisions have to be made when there are no neat guidelines to follow. Basically, Mr. Richterman said, most rehabilitation centers use the Valley Forge method, that is, teaching rhythm techniques as opposed to simply holding or tapping a cane. Mr. Richterman said that differences concerning the approach towards the individual are difficult to put down on paper. Mr. Williams said some of these decisions have to be made on the spur of the moment, that is, within an hour's training session; there is a constant diagnostic process that goes along with the rehabilitation training. Mr. Bledsoe said that there has been some attempt to get these factors down on paper. He referred to several items listed in the General References. Mr. Bledsoe believes that rehabilitation people have the same problem doctors do, namely, they don't write down enough of what they are doing as they are going along so that it will be useful to others.

Mr. Bledsoe said there are certain factors in cane length, weight, etc., that are subject to scientific measurement. He said we should pose the kind of problems to people at MIT for which answers can be found. In other words, don't ask them to solve the great mysteries of life. Mr. Richterman suggested several questions that the instructor must face: When should the trainee be taken out doors for the first time? When do you expose him first to a busy area? When do you start training him on transportation systems? Could research help with these questions?

Dr. Barnhart raised the question as to what mental process these people go through in arriving at these decisions. He went on to ask if there weren't some factual evidence which they have to have to go on. Everyone has to have some kind of evidence on which to base his decisions.

Mr. Suterko asked if there had been a study of the effect of the emotions on the sensory apparatus. The Chairman answered that there is some but not enough information on the effect of the emotions. We do not believe that sensory input is affected by the emotions, but we do believe that the reaction the individual makes to sensory inputs and processing may be so affected. We need specific research on this subject with respect to mobility by blind persons. Mr. Silver and Mr. Williams said it might be useful to study the mobility trainer to determine what goes on inside his mind as he makes these decisions concerning what he will ask the trainee to do.

Mr. Williams said he would not like to have a set of factors listed on the basis of which the trainer would have to grade the trainee 1,2,3. There are simply too many factors. On the other hand, on an interview basis, the specialist ought to be able to react to a large number of factors. We must have some kind of guidelines in teaching the instructors. Otherwise, he said, the instructor will have to go through all the experience which has been accumulated over a long time by the people now in the field.

Mr. Werntz asked if the performance unit should not be standardized. He said that at St. Paul's and other centers one question is standard, namely, Is the trainee ready to go outside? At The Seeing Eye, however, they start training outdoors immediately.

Mr. Richterman agreed with the comment that there are some manuals on the subject, including one published by IHB, which indicate there are taining phases, but they are not rigorously defined. Mr. Bledsoe said that there should be some way for the trainer to check his own "batting average", that is how well he has done in determining each of these phases, and how well the trainee does in moving from phase to phase. He went on to say they would like to know how well the graduates of various rehabilitation centers perform after they leave. Dr. Hoover and Mr. Bledsoe agreed it would be possible in the Blinded Veterans Research Project to find out how well people retain their mobility training. The first study of veterans only pointed out how well they were doing in terms of employment. Dr. Hoover listed some questions which might be asked:

Dr. Hoover:

"To me, this whole thing boils down to several questions. The first would be something like, What is important to use from the remaining senses? It always amazed me, in a school for the blind for instance, how many people can become good piano tuners. They have nothing unusual in the way of ability to become piano tuners, but the guy who is teaching the piano tuning can do this and do it very well. The same way with music. In some of the older schools at least, 95 to 100% of the people come out able to do and interpret music pretty well, and there is nothing unusual about this cross-section but they have had good music teachers here, people who know how to do this thing. The same way with even vision, when you have vision, how to use this remaining vision. These are the things we have to know, then after we know these, how can they be economically and precisely taught so that they will mean something. The job of finding the space capsules for instance, sounded like a pretty easy one until they sent people up to do it, and they found that they really had to teach people how to look for these things. And you can see this in everyday life. Lots of people can go out hunting bear and deer, and they'll never see any and the guy right beside him will kill his limit every time because he knows what he is looking for and he knows how to look for it. The things that are important are the remaining senses and how to teach their use and you all do this all the time, I'm sure.

But you don't always separate it out into this and this and this, but if we were asked about this you would all finally realise you are doing this sort of thing. After this, you can then find out what can be taught or what is important, and where the need is for refinement of these techniques. Is it a refinement in the sensory techniques that you need most in this individual, or is it a refinement of his motor techniques that is more important? Lots of people have these things that just come naturally to them. You don't have to teach them much about some things. Others you have to spend a lot of time on. Then I think another area which lends itself to investigation ,as Mr. Silver said, is how you select those who can best impart all those things that you know they must know. This is important. You can take lots of people and they can spend 10 hours a day for twenty years and they never teach anyone to travel. You've all seen that. So this is important. Then I think you have to investigate the old, the new, a combination of whatever instruments there are that help in this process. Do we need a new breed of dog? Do we need a new cane? Does the dog's harness need to be refined? Where does the cane tip need to be refined in order to make these remaining skills and either motor or sensory more effective to this individual? And I think what most people forget is that there are time factors involved. We set up a period of time, 6 weeks, 3 months, whatever it is. This may be far too short. Maybe the motor skills and the sensory skills are both something that you have to continually practice just as you do medicine or golf or anything else. You have to keep at it and you shouldn't (in my opinion) ever look at mobility as something that you get good at and you stay good at. I think it is something that you have to keep after, you have to keep practicing. Some people will be better than other people. Some people won't get good and some people will get very good. I don't think you should ever stop, if there is still rehabilitation or vocational potential. I know one of the greatest eye surgeons inthis country who was ready to quit surgery because he couldn't stick a knife through an eye, and the last day of his surgical residency another man came in and told him he was going to help him do this particular cataract, and it changed his entire career. I think many times mobility would be changed with respect to the individual's outlook if you have enough time and you don't give up too easily and don't consider them as finished products at any one place along the line. Of course for economic reasons you have to set up certain logical goals, practical goals. I think in all these areas you can develop research projects and come up with something that is important and something that can be set down, and I think many of the individuals right in this room can contribute a lot in each of these areas."

The Chairman commented that there are several areas which it would be useful to investigate. Some of these are: a) The fact that some remaining sensory channels are not as meaningful as others to the newly blinded person. For example, the sense of touch is much more reassuring and important than the more complicated auditory sense which must wait upon time for the individual to maximize its usefulness; b) we need to know more about kinesthesis with particular reference to muscle memory in the role of navigation in mobility; c) we need to know more about how trainable these senses are; that is, in terms of how much information the individual ought to store. It is reference to storage in the human brain that permits the individual to operate. What kinds of special information need to be stored now in the brain which might not have been required before? Indeed we need to know how useful the information is which has been stored by the adventitiously blind when the congenitally blind could never have had access to this information in the first place; d) is there any order in which the sensory channels should be trained?

Mr. Bledsoe raised a question as to which area of science is involved here. The Chairman answered that it requires an interdisciplinary approach in which the technical and social scientists must join with the rehabilitation people. When the problems are spelled out and the proper questions are raised, there should be no difficulty with this interdisciplinary cooperation.

Mr. Bledsoe raised a question as to whether the rehabilitation people should formulate some hypotheses which then could be proved or disproved. The Chairman said this might be a useful beginning, but that you do not have to have a neat set of hypotheses. You merely go on collecting hypotheses without worrying about whether they are probably valid or probably not valid. Then you let the scientist sort out the particular ones which in their opinion lend themselves to initial study.

There was no agreement among the mobility rehabilitation people as to what the length of the cane should be. Mr. Williams said that under certain conditions a longer cane is required. Therefore, a cane which could change in length could be developed. This would be a useful piece of hardware, and would probably provide a positive motivational factor in mobility.

There is no scientific evidence as to whether the arc transcribed in the search pattern of the Hoover technique provides maximum protection under all circumstances or even under normal conditions. Is there not a more efficient search technique, such as a sinusoidal search pattern as opposed to sampling the environment at the extremes. The Chairman said that an MIT group was investigating the question of what kind of information a cane really transmits from the environment to the individual. This has not been investigated up to now. The important thing is to set down this data in such a way that it can be communicated readily to any other person. It could be understood then by mobility trainers other than the very top few in the field.

Dr. Hoover mentioned there are certain specific sounds which people might be taught. He mentioned the clicks from traffic signals which very few blind people know about or pay much attention to, yet these can be perceived.

Dr. Hoover mentioned some of the things a cane should do: it should tell you whether there is anything in front of you; whether you have a safe place to place your foot; and it should give you a certain amount of information concerning the terrain. Information can be transmitted to the human being through tactual sense or through kinesthesis and under certain circumstances by hearing. The type of cane might vary depending upon the needs of the individual. For social events a light wand-like cane may be adequate or one cane might serve all purposes if it were constucted in varying lengths. On the other hand it may take a group of canes. Chances are there are certain things on which probably everyone would agree, others might require investigation.

Mr. Richterman said that IHB uses 8 grades of sandpaper to give the trainee some idea of tactual discrimination. They use 8 dowels of different lengths starting from 42" on down to get some idea of muscle perception. He said he doesn't know if there is anything scientific about this or whether there is any carry-over to the individual's performance. He said he would be glad to have tests however, which might be more scientifically validated.

Mr. Silver said he is interested in the individual's awareness. This includes reaction time to all kinds of cues. He is interested in the clues which can be picked up by the organs of equilibrium, such as changes in the pitch of the sidewalk. Also how fast can a person determine that the cane is starting to go off the curb? And how small is the angle change he is able to perceive? He said that he believes things of this kind and others can be done faster in the laboratory.

Mr. Debetaz raised the question of the follow-through, that is, do the people from the rehabilitation centers look in on the client periodically after he has left the center?

Mr. Silver said that in the follow-through which was to compare the twelve- and sixteen-week programs at St. Paul's, there was no opportunity to do a thorough analysis of the retention of mobility capability. It was based largely upon the individual's word and in some cases, his counselor's word. Mr. Debetaz was asked if The Seeing Eye made such a check and Mr. Debetaz said they do. They first do it by correspondence. There are two people on the staff who personally visit the people who don't reply. Further, if some difficulty with the dog is discovered, an instructor is sent to check on the situation. Of course, there are people who come back for a replacement dog and this gives another opportunity for a periodic check. Also a number of blind people drop in at the school on their way through Morristown. Mr. Debetaz felt that this feedback is very important because it gives them constant check on how well the program is working over the years.

Mr. Richterman said that I. H. B. has no formal program for checking on former clients but he said they would probably uncover any difficulty because they provide other services to the same people. Occasionally, too, someone will call who has moved to another neighborhood and wants to be reoriented.

The group agreed that a large-scale follow-through study would be of considerable value. The Chairman added that such a study would determine whether retraining were necessary. This would be an expensive study which could not be undertaken by a single rehabilitation center, but is within the scope of government funding. It would be desirable to use the methods of the New York School of Social Work, that is, interview a cross-section of the blind population in their own homes. People who answer letters or fill out survey questionnaires probably do not represent a cross-section.

Mr. Werntz pointed out that in their program as many as 50 percent of the students have been at The Seeing Eye before. Some of these individuals have had a dog for 10 or more years. He raised a question as to what contribution the experience of these mobile individuals makes upon the rest of the class. Here may be another desirable element, that is, the incorporation of the experienced skilled traveler in the training situation. This would permit a three-way exchange of information. He asked if this situation occurred in the cane travel program. Mr. Malamazian said that to a certain extent this occurs in the Hines program. People do not all start at the same time and finish at the same time. There are bound to be people who are already experienced at traveling who are there at the same time as those who are just beginning. Mr. Malamazian went on to point out that this provides an opportunity for those blind persons who never met anyone who is blind and who is also a skilled traveler.

Mr. Bledsoe pointed out that although the Veterans Administration is in touch with veterans for various reasons throughout the veteran's life, the new emphasis on decentralization makes it difficult to maintain a centrally coordinated program to follow through. On the other hand, if the importance of this were stressed, it is certainly within the scope of VA to set up a special program for this purpose.

Dr. Hoover pointed out that once there is a standardized program for training mobility specialists it should be easier to set up the follow-through. The increased efficiency should allow some time for these mobility people to follow through. Also, there should be some uniformity across the reporting and analysis. He pointed out the difficulty in evaluating what is going on in dog guide schools. He pointed out that there may be a deterioration in the person's mobility training which would lead eventually to his using the cane very little if at all.

The Chairman moved the discussion on to the next point on the agenda: travel by people with residual vision. Dr. Hoover said that about 70 percent of blind people have some residual vision.

The Chairman asked what limitations this partial sight exerts on mobility. He said that the New York School of Social Work survey pointed out the fact that a substantial number of people with residual vision are not mobile. People with visual acuity as high as 10/200 to 20/200 did not get around very much.

The Chairman asked what use low vision aids have in mobility training. Mr. Williams answered that you must certainly include these in your mobility training programs where they apply. It is difficult to estimate the individual's efficiency in using his remaining vision. He said that Mr. Suterko had found one veteran who used telescopic lenses and it contributed to his mobility. Mr. Suterko said that the individual had no more than 2/200 vision and had become efficient in his travel. He pointed out that the individual was highly motivated and was not preoccupied with cosmetic considerations.

Dr. Hoover commented:

> "As far as research is concerned, here is the place where you need research in order to record and find out what techniques you used in teaching this man and what he used that you didn't teach him. This is up to now a completely undeveloped field...People just put (the glasses) on and they sit down and you say they are holding them too close or too far away, you have missed a real systematic program of teaching these things. In our field we have a parallel for that in the indirect ophthalmoscopy, where we examine the back of the eye. Everybody is used to using what we call a direct ophthalmoscope. You spend five or six years learning to do this and you can do it pretty well. Somebody hands you an indirect ophthalmoscope and everything is a mess. You just can't see anything. But after a year or two, if you have the proper instructor and know the techniques to use, you can use this much more efficiently than you can the other. I'm sure the telescope is much easier than the indirect ophthalmoscope. And yet nobody has really recorded the techniques that a person needs in order to make this easy and efficient for him. Now you evidently have some experience like this and a few others have isolated experiences. Now this is an area where you could really do a great service."

Mr. Williams said that in the Hines program, 50 percent or more of the veterans had some residual vision. There were serious mobility problems in nearly every case of residual vision. Some changes in the procedures were required, particularly in pacing, but in most cases these people with residual vision were made mobile. He said perhaps a large factor in this was that they were brought out of an unsympathetic environment into a sympathetic one. People thought because they had some vision they ought to do very well. At Hines the people approached them with the idea, "We know you have problems and we'll try to help you with them."

Mr. Bledsoe raised the question of the philosophy of using occluders with these people. Should one teach them to use what little sight they have left, or should one teach them to operate as if they had no sight? Mr. Williams says he is in favor of trying to teach them to use whatever sight they have. Then those things which must be performed with a cane are added to this capability. He said adding these tools such as a cane or a dog or the arm of a sighted person is something which may not have been tried before to make up for the difference between what they can do with sight and what they cannot do. He said he was not sure whether techniques for improving visual efficiency were good. These might be studied as a research area.

Mr. Williams said one of the important factors here is that these people are put into motion. When they are in motion, they themselves can judge what their visual efficiency really is. This is something they may not have felt competent to do before. Miss Baird pointed out that the use of residual sight must be implemented by these skills developed from other sensory channels.

There was then a discussion between Miss Baird and Mr. Williams concerning the fact that these additional tools must be sufficiently dignified to be acceptable

to the partially sighted person. They said it may take a considerable amount of time for him to assume an attitude in which the additional tools are acceptable. Dr. Hoover said that he thought Miss Baird was referring to the fact that if people have a little sight they tend not to fully develop their skill in using the other senses. Miss Baird said that at school the partially sighted children run into many more things than the totally blind ones. They are not taking advantage of auditory cues. Their sight gives them inadequate and inaccurate information. Mr. Williams believes that in this case occluders might help these individuals develop skill with the other senses.

Mr. Suterko stated that the individual may encounter quite different conditions in traveling from one point to another. In certain places, his residual vision may be quite adequate. In others, he may operate only with considerable difficulty and hazard. Miss Baird said some partially sighted people have great difficulty in sunlight and yet operate fairly well when they are not in direct sunlight. Others can make no use of their partial sight under conditions of low illumination.

Mr. Richterman questioned whether these partially sighted people could develop their skills to the same degree as the totally blind. A factor that may be important here is that a sighted instructor or a partially sighted client can operate with a blindfold, knowing that when they remove their blindfold they have their partial sight restored. According to Mr. Richterman there are some individuals for whom occluders would bring on a traumatic experience. You have to be careful in using occluders. He said he would not like to see any rule of thumb on the use of occluders for the partially sighted. Mr. Richterman said that instructors at I. H. B. are now familiar with techniques used to increase the efficiency of residual vision. They can now work together with the people in the low-vision clinic. The visual rehabilitation counselor frequently goes along with the mobility trainer and notes where lenses are being used and where not. Re-fitting is sometimes required for mobility purposes.

The Chairman pointed out that very little is done at the extreme low end of residual vision. There is no research on light amplifiers, for example, which could be miniaturized and provided to people who are beyond the help of regular optical aids. He said this is also true of people with low residual hearing, that approximately one-half of the deaf-blind population has such severely impaired hearing that commercial hearing aids are not useful. The development of special low residual hearing aids might be a useful research project. Although only a few hundred people might be helped by these two research projects, at the same time these are the persons whose vocational problems are most severe.

The Chairman pointed out that at the Visual Impairments Subcommittee meetings on rehabilitation codes, often many of the factors in low residual vision are not carefully measured. The tendency is to indicate a low static visual acuity with occasionally some information about field. But there is not as comprehensive an analysis as would be desired for rehabilitation purposes. Dr. Hoover agreed.

The Chairman then raised a question as to whether rehabilitation centers ought to be involved in the actual research porject. Should some research projects be conducted on the premises? Should they be involved in cooperative projects with research staff based elsewhere? In starting to answer these questions he said there are some people who believe time cannot be taken from the rehabilitation process to participate in research. There is little staff time available and the individual's training should not be interfered with.

Dr. Hoover said he doubts whether centers have the necessary personnel or the orientation towards research. Research on a clinical basis, however, could be pursued at the centers. Evaluating new instrumentation or development is beyond the scope of current rehabilitation centers. He feels that this development of new instrumentation in certain research projects is best left to the technological, social science and medical centers.

Mr. Silver said the centers should cooperate in terms of limited but active consulting, and in some cases might also help evaluate the factors involved in selecting subjects and comment critically on certain parts of the research project which have to do with sensory deprivation. From the professional standpoint, this is a useful addition to his training. He pointed out that in the peripatology programs this cooperation in research projects should be useful in training the new specialists.

Mr. Williams said that in spite of the complications involved he believes it could be done and careful analysis should be made of the participation, project by project.

Dr. Hoover pointed out that getting the researcher to do some of the leg work is often useful. If he is exposed to some of the aspects of mobility rehabilitation, he may come up with more realistic research findings.

The Chairman commented that perhaps the reason so many projects have gone on and on, failing to reach definitive conclusions, is a lack of communications with the rehabilitation personnel. In some cases the products of research have taken useful information from the blinded person instead of adding to his data.

The Chairman said that there has been a lack of communications in the direction of researcher to rehabilitation personnel also. He said that progress reports of certain research projects were not distributed to the rehabilitation people or even to those who are trying to stimulate research programs. There should be systematic communications channels for research projects.

Dr. Hoover suggested that we are pretty well along with our research but have not worked out techniques for applying the research. This is probably true in the mobility area. It is this technique of applying what is already known that presents a problem. The Chairman added that until we have applied what is already known, we cannot determine what is still left to do. Take, for example, tactile maps and binaural training tapes. These have been developed but have not been refined to a state of usefulness because the techniques for using them did not exist.

Dr. Hoover commented that in addition to getting good research off the ground, you have the problem of its mushrooming into areas which then require justification. This may be one of the critical factors in research projects. Should there not be some attempt to bring critical judgment to bear early enough so that we do not continue indefinitely on projects whose ultimate value is negligible?

Mr. Bledsoe said that perhaps the greatest research need is in finding out what the individual will accept in the way of additional aids, training, etc. The scientist may come up with findings which can then be applied by the rehabilitation people, and yet there may be no addition to the capability of the individual. This area of "consumer acceptance" is one which might be fruitfully studied, perhaps by human factors people who are knowledgeable in sensory deprivation.

Mr. Debetaz said it is difficult for the rehabilitation specialists to come to the researchers and pose specific questions that are researchable. So far, he said, they have not come up with a problem which they can say flatly needs study.

Mr. Williams said we know that there are two aids-- the dog and the cane-- which enable people to function when their remaining sensory channels are inadequate for certain conditions. He raised the question as to whether these tools are themselves completely adequate. He answered this himself, saying, "We know that under certain conditions they are not." Might it not be useful to find out what is lacking in these two aids? How can we assist the individual to compensate for what is beyond both his own capabilities and those of the cane or the dog. Even with a dog or cane, the blind person does not travel as well as the sighted person.

Mr. Williams raised a question concerning the ability to travel in a straight line. Some people can continue in a straight line up to a hundred feet, while others cannot. Is it desirable to extend this to 200 feet? Can this be trained? Can it be aided by instrumentation? He believes a gyro-like device might be useful.

Mr. Rives asked if a useful area of study might not be how to acquire information about the environment above the waist. The long cane works reasonably well from the waist down, but how about the other area? Mr. Bledsoe asked if the Haverford-Biophysical Electronics device might be made smaller. The chairman answered that reliability was the first problem to be solved, and that considerable development would be required to miniaturize and ruggedize the instrument so that it would be readily head-mountable or cane-mountable. It could be done but would be a fairly expensive project.

The Chairman commented that it might be advisable to say to the technologists that at present it is our considered opinion that a substitute for a dog or a cane is not feasible. Therefore you ought to concentrate on supplementing the individual's trained capability. Specify what kinds of information you want to give to the individual. Researchers at M. I. T. have come to the following conclusions: a) We will do basic research to find out how the individual functions when information is recoded from the visual and auditory channels into remaining sensory channels; b) We must find out if it is possible to supplement the use of the cane, the dog, and trained capability for mobility purposes.

Mr. Rives asked if the following isn't a fair set of criteria to give technical researchers: a) A person must detect an object a certain distance away so he can react to it. This might be three feet or some other distance; b) He must have information about the area above the waist which a cane does not find. One or more of these devices would function when the sensory channels were not at their optimum processing level, or when the information could not be picked up by the individual with his cane, his dog or his senses.

Dr. Hoover said that one of the first devices developed by the Signal Corps gave range information, but not for all objects under all conditions. There was also the problem of transferring the information successfully to the individual. He said he wonders if the techniques for using the Signal Corps and other devices have really been explored. The period of training in the use of the device may have been too short or not well prepared. Mr. Werntz said that one of the difficulties with these devices is that the individual has to follow a certain scan pattern in order to find these objects. The device itself simply faces a given direction. If the device were small enough to be head-mounted and satisfy cosmetic considerations, the individual would have a pretty good method of automatic scanning.

The Chairman commented that thus far technologists have not developed devices which reliably under all conditions present the right kind of signals for human comprehension, are ruggedized and fail-safe. In short they have not developed a device which will permit an individual to travel in safety under as many conditions as he can with a cane or a dog. They should therefore work toward somewhat less ambitious goals and think of the ultimate device as an addition to the natural capabilities.

Mr. Rives asked if the technologists could not be asked to do a relatively simple thing, that is, build a better cane. The Chairman answered that this is possible provided we tell the researchers what we want built into a cane in terms of the information needed by the blind person and the conditions encountered in its use. Mr. Bledsoe commented that one way to learn this is to watch an instructor working with blind trainees. Mr. Rives agreed that a small group of blind trainees and rehabilitation specialists could probably communicate enough information to the technologists so that they could design better canes.

Mr. Bledsoe quoted Dr. Hoover on what a cane can and cannot do:

"....It can unerringly detect steps up and steps down, it can unerringly detect holes, unevenness and types of terrain, it can detect objects of any size that may happen to be situated in the footstep path of the traveler. There are several things a cane cannot do. It cannot determine direction, it cannot hear, it cannot talk, it cannot smell, it cannot think, it cannot furnish the energy for the traveler and it cannot see."

Mr. Bledsoe commented that engineering people do not know the literature available from the rehabilitation areas. The Chairman commented that although this literature is available, it does not provide engineers with precise design data. He agreed that the broad descriptive data should be pointed out to the researchers, however.

Mr. Rives then asked for specific research suggestions. They are as follows:
1) Mr. Richterman says he would like to see a muscular memory device developed. After the measurement tool is developed perhaps the training procedures could then be improved. (Miss Baird and Mr. Silver disagreed on the usefulness of such a device.)
2) Mr. Richterman would also like to see devices developed for measuring cutaneous sensitivity so that this sensory channel could be better trained.
3) Mr. Richterman said that laboratory-type training to identify specific sound cues would be advisable.
4) Mr. Silver suggested that some kind of tiltable electric treadmill would be useful in determining a person's ability to detect changes in slope and to follow a straight line.

5) Dr. Hoover said that in addition to a good cane, we don't have a good tip, and this ought to be developed.
6) Dr. Hoover said we need a study to learn whether the techniques now being used are proper and effective.
7) Mr. Richterman suggested a study of what causes people to fail in the mobility program. An analysis of these factors could lead to better training techniques. Mr. Richterman went on to say that there are a variety of other subtle cues such as a change of slope in approaching a curb, wind effects, etc. which might be pointed out to the individual early in the game. Perhaps some technique of forcing it into his attention might be used in the beginning.
8) The Chairman suggested a study which would bring together all the data in the hands of the rehabilitation specialists and which could be sifted by the social scientists and put into one document for study by researchers coming into the field. As it is, the literature describing what the experienced specialists in the field know, is incomplete and scattered.
9) Improve the cane.
10) Develop a better collapsible cane.
11) Study how effective the arcing technique or search pattern is.
12) Set up a good bibliography as a start towards an analysis of programs.

The Chairman interjected that he hopes in the peripatology programs the students have a research orientation and are thinking about researchable problems, so that when they get into the field, they can test these notions to see if they warrant further consideration.

13) Mr. Richterman said that lack of motivation and lack of ability to orient in the environment are very important factors which should be studied.
14) The suggestion was made that a study be made to determine readiness for mobility. Several participants dissented, however. They said that people should not be screened out arbitrarily, that some effort ought to be made to train everyone who applies. The difference of opinion seemed to be based on the question of whether you want to screen out people or whether you simply want to know more about them before they begin training.
15) The battery of tests now available needs to be analyzed. Perhaps new tests should be devised on the basis of this study.
16) The suggestion was repeated that navigation devices such as a gyro-system, better tactile maps, etc., might be useful. The Chairman commented that only two research projects in navigation were known to him. One is the Master's Thesis of Nathan Sokal at M. I. T. in which the Perkins School gymnasium was used as an obstacle course. Information was presented to the individual as to the distribution of objects. The objects showed up on a pegboard which he carried with him. The other research in the navigation area was conducted at the University of Washington and later at the American Printing House for the Blind. They tried to devise symbols which could be easily read out with cutaneous sensing.
17) The suggestion was repeated that we develop a device which will locate objects above the waist.
18) The suggestion was made that a study be made of the people who actually apply for admission to a dog guide school or to a rehabilitation center. What characteristics do these people have? How do they differ from the people who do not apply?

19) We need measures of the success of mobility training. The New York School of Social Work study indicated that four-fifths of the people who travel are not satisfied with their ability.

20) The suggestion was made that we study the factors involved in bringing these programs to children. This is a fruitful new area for investigation, both from the rehabilitation standpoint and from the research standpoint. A cane more suitable for children would be appreciated. Children tend to find existing canes unsatisfactory.

MOBILITY RESEARCH CONFERENCE

October 11, 12, 13, 1961

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KEYNOTE ADDRESS

MOBILITY: ITS POTENTIAL, ITS SCOPE

R. E. Hoover, M. D.

As one warms to this subject, it assumes so many interesting faces it is hard to limit the scope to something possible and practical. Mobility really encompasses all of motion. This means all movement of any or all muscles, in the active sense, such as the movement of a muscle or muscles in walking, running, sitting, rising, eating, smoking, smiling, fighting, talking, etc. It also means motion in the more passive sense such as transport by car, plane, train, etc.

Most of the time it is difficult to separate a thing we take so matter-of-factly into its essential component parts. It is not hard, however, to realize the necessity of all the above-mentioned to the average human being.

Because everyone is so accustomed to all these movements with their satisfactions, the individual seldom stops to ponder if mobility means more than getting from one place to another. It is possible that careful interrogation of a person without sight would soon bring to light many needs for mobility rather than just the necessity of getting from one spot to another. It can be an antidote to frustration; it can be a catalyst for relaxation; it could be a manner of non-verbal expression; it could be a neuro-muscular expression of a personality pattern.

Whatever it is, you here at this conference should direct much of your thinking and effort into solving the more essential and practical problems faced by the average person who has not had, or who has lost, vision to such a degreee that a major part of his movements, expression and navigation will be done by use of his remaining acumen, initiative and potential. It is necessary on many important occasions that he do this without being able to judge its effect on the rest of the watching world. Herein lies the greatest barrier to the universal eagerness to participate.

There is neither the time, nor is it my desire, to try to outline all the facets of this great complex worthy of your able and fertile attention. It is appropriate, however, to tell you from my own experience in what directions I think you might proceed without the need for unlimited time and without the facility of a Kennedy-sized budget and yet contribute to the propogation of worthy skills in a most satisfactory and practical manner.

Please recall all the aspects of movement that I mentioned earlier and remember also that each of these requires detailed investigation and attention. Allow me now to examine the obvious in a random-like way, not necessarily in the order of importance, and to suggest definite areas where research would be of unquestionable value and other areas where it might be more rewarding than is currently supposed.

The following remarks pertain to the very limited and yet relatively unexplored area of mobility from place to place on foot. Considering the obvious, we ask how is this to be accomplished by the person in relatively good locomotor condition except for useful vision? The possibilities are not many. The foot traveler either "goes it alone" or goes with someone or something.

If he goes alone he uses all his remaining courage, instincts and perceptual abilities (sensory or other) to carry him where he wants to go. How successful he is will depend on native ability, additional physical and perceptual defects or endowments, and the training received. How can more training increase his abilities, compensate his defects and take full advantage of his endowments?

If he goes with someone, they may or may not obtain the objective in a mutually efficient and satisfying manner. But the techniques of the guide and the guided should be analyzed for the possibility of improving transferrable techniques which can successfully be taught.

If he goes with something, his practical choice at present is the dog or the cane. Here again his success is dependent on his native ability, additional physical and perceptual defects or endowments and training received.

If the dog is used as the major guiding device, its native ability, physical and perceptual defects or endowments and training will be important also. We might ask these questions: is the dog properly blessed with intelligence, health, ability and stamina? Is it equipped with the proper harness and training or can all these be further investigated to advantage?

If the cane is used, the need for investigation increases. For instance, is it known if the traveler is using the best type of cane as to material and weight? Does it relay all the aural, thermal, tactual and other information? Is it the proper length? Is it adjustable to all conditions? Can it be made adjustable and adaptable? Is more than one cane necessary? Is the tip satisfactory - does it relay information, does it slide, is it durable? Are the traveler's cane techniques efficient and safe?

Are the collective techniques now employed by blind travelers in fact the best or is there a need for an entirely new way? We cannot really answer this question at present. Therefore, we must go to the superior blind foot traveler and find out how he succeeds and determine which of his techniques are good and how they can be improved. Then we must find ways to transfer them to others.

You will notice I have avoided any of the more glamorous electronic, psychological, psychophysical, psychosocial phenomena. It is not my intent they should be forgotten, nor will they be, since they have scientific appeal.

If I can be helpful at all, it is to remind you that the commonplace, the mundane, the practical and the adaptable still need your expert investigation and arranging.

MOBILITY TRAINING PROGRAMS
Report of a Survey
by James W. Linsner

The Division of Research and Statistics of the American Foundation for the Blind recently conducted a brief survey of agencies offering cane travel instruction to blind persons. The agencies surveyed were of three general types: 1) agencies operating under a department of the federal government or a state government (this group being comprised largely of state commissions for the blind and Veterans Administration Hospitals that have special programs for blinded veterans); 2) agencies that are supported by voluntary contributions and that serve a relatively small geographical area, such as a city or county; 3) residential schools for the blind. Columns labelled A, B and C in the tables below refer respectively to these three types of agency.

The mailing list was compiled principally from three sources: 1) the Directory of Agencies Serving Blind Persons in the United States and Canada, American Foundation for the Blind, New York, 1961; 2) Rehabilitation Centers Today, (Rehabilitation Service Series No. 490), U. S. Government Printing Office, Washington, D. C., 1959; 3) the personal knowledge of specialists in the field of rehabilitation. The table below shows for each category the number of questionnaires sent, the number of completed questionnaires received, and the number of agencies that claim to offer a program of cane travel instruction to totally blind persons.

	A	B	C	TOTAL
Number Sent	50	36	49	135
Number Received	43	29	39	111
Number Offering Cane Travel Instruction	36	19	25	80

Except in seven residential schools, the same instruction is offered also to partially-sighted persons. When asked to specify the conditions of visual acuity on which clients are accepted for travel training, either the phrase "legal blindness" or the figure 20/200 appeared in 30 of the replies. Seven agencies use a more stringent criterion, varying from 20/300 down to light perception only. Two agencies use the more liberal criterion of 20/100. Following is a list of other criteria, together with the number of agencies specifying each:

Individual need	13
Progressive blindness	6
Reduced visual field	5
Visual efficiency	4
Night blindness	2

When asked whether partially-sighted clients are referred to an appropriate source for low-vision aids, 66 agencies replied "yes" and 8 "no".

This report then is based on information from 80 agencies that offer a program in cane travel instruction. Our interest naturally centered about the three basic elements of any instruction program: the students or clients, the program itself and the instructors.

THE CLIENTS

Nine questions were asked concerning the number of clients served, how clients are examined and evaluated before training, how their progress is followed during training and what is known about the occupations of those who have completed training.

1. a. How many clients received cane travel instruction in the twelve month period ending June 30, 1961?
   b. How many of these did not complete the mobility training program?
   c. For what reasons?

	A	B	C	ALL AGENCIES COMBINED
Number of persons served	1463	991	241	2695
Average number per agency	47.2	55.1	10.6	38.5
Percent not completing training	18.1	11.4	23.7	16.1

The percentage of residential school students (column C) not completing training is rather high, since some schools offer a program that extends over a period of more than one school year.

The reasons most frequently given for clients' not completing training were: illness and physical disabilities other than blindness, lack of interest or motivation, lack of inherent ability and lack of directional sense.

2. Are statistics readily available regarding the a) present age, b) sex, c) degree of vision, and d) age at loss of sight of clients accepted for mobility training during the twelve month period ending June 30, 1961? If so, please enclose a copy of this information. Note: Do not submit individual case histories.

Apparently most agencies maintain records in such a way that the information requested is not readily retrievable. Too few agencies submitted data to warrant tabulation.

3. a. What percentage of your clients are from rural areas?
   b. Do they receive special instructions for traveling in rural areas?

	A	B	C	ALL AGENCIES COMBINED
Avg. percentage rural clients	32.5	15.3	26.6	27.1
Number of responses to 3. b.	27	11	11	49
Number "yes" responses to 3. b.	20	9	9	38

4. Which of the following examinations does the client undergo either before acceptance or during the training period?: General medical examination; Ophthalmological examination; Aural examination including audiometric test.

	A	B	C	TOTAL
General medical examination	31	18	21	70
Ophthalmological examination	34	19	22	75
Aural examination (routine)	11	10	17	38
Aural examination (where indicated)	9	1	1	11

5. Is a psychological evaluation made of the client? If so, what specific tests are administered?

	A	B	C	TOTAL
"Yes" response	17	12	19	48

Of these 48 agencies, only 32 specified the tests administered. Below are listed the most popular of the tests with the number of agencies administering each. Residential schools, who administer principally the Hayes-Binet and/or some form of the Wechsler test, have been omitted from this tabulation.

Wechsler-Bellevue Adult Intelligence Scale	13
Kuder Preference Record	7
Minnesota Rate of Manipulation Test	7
Minnesota Multiphasic Personality Inventory	5
Emotional Factors Inventory	4
Pennsylvania Bimanual Worksample	4
Strong Vocational Interest Blank	4
Purdue Pegboard	3

6. Are the results of this evaluation easily accessible to the mobility instructor?

Of the 48 agencies who replied "yes" to question 5, 47 replied to this question. All 47 replied "yes".

7. How is information exchanged between staff members regarding the progress of individual clients?

		Exclusively
Staff conference or faculty meeting	49	32
Progress report or written memorandum	29	7
Personal contact	12	0

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It is interesting to note that the verbal exchange is much preferred to the written report and that the staff conference is often the sole means of information exchange. Note however that no agency relies exclusively on personal contact as the means of information exchange.

8. Has any follow-up survey been made of past clients by means of a questionnaire or personal interview? If so, please enclose a copy of report or statistics compiled as a result of this survey.

Fourteen agencies claim to have made a follow-up survey. Only one furnished a copy of the report issued, while five more explained that the interview was conducted informally and that no form was used and no report issued.

9. What percentage of clients who have completed the mobility training program are:

____self-employed

____employed by another

____housewife

____student

____unemployed

____other (specify)

Of the 13 replies to this question, only six appear to give reasonable estimates based on actual records. Since the number of replies is so small, tabulation is unwarranted.

THE INSTRUCTION

Four questions were asked in an effort to reveal the character of the training itself.

1. Does your agency teach the Hoover (long-cane) technique? Any other? Describe briefly.

	A	B	C	TOTAL
Hoover technique	24	15	22	61
Modified Hoover technique	6	3	0	9
Other	6	1	3	10

(The modification referred to in this table was stated in most cases as being a shorter cane.)

2. Is this instruction given at a center, on an itinerant basis, or both?

	A	B	C	TOTAL
At a center	11	9	24	44
On an itinerant basis	9	0	0	9
Both	16	10	1	27

Thus the 80 responding agencies represent 71 center programs (including 25 residential schools) and 36 itinerant programs (including one residential school).

3. a. What is the total number of hours of instruction in cane travel the average client receives?
   b. If the total instruction time varies appreciably from client to client, what are the customary maximum and minimum number of hours?

	AVERAGES			ALL AGENCIES COMBINED
	A	B	C	
Average	78.7	82.3	51.2	71.7
Maximum	78.4	74.2	77.0	76.9
Minimum	35.1	27.2	29.3	31.7

(Some maximum figures are lower than averages, since not all responding agencies furnished both figures.)

The range in the replies from least to most hours of instruction is quite startling. In the table below, note that one agency offers an average of 2½ hours of instruction, while another in the same category offers an average of 320 hours.

HIGH AND LOW FIGURES

	A		B		C	
	High	Low	High	Low	High	Low
Average	320	2.5	240	15	95	12
Maximum	400	5	240	20	160	12
Minimum	260	1	120	2	80	3

4. What is the ratio of instructors to students in the mobility program?

Apparently this concept is quite familiar to residential schools, and the figure in column C is probably reliable. Many other agencies submitted figures that are clearly incompatible with the number of instructors employed by and the number of clients served by those agencies. Consequently the ratios in columns A and B are probably not accurate and should be somewhat closer to the figure in column C.

	A	B	C	ALL AGENCIES COMBINED
Average ratio	1:7.2	1:3.9	1:10.1	1:7.2

One further question was asked concerning interpretation of services.

5. How are the services of your agency interpreted to the client's family?

a. by the home teacher
b. by the rehabilitation counsellor
c. by the mobility instructor
d. by the social worker
e. by the client
f. by letter
g. through family seminars or group therapy sessions
h. other (specify)

	A	B	TOTAL
a.	23	6	29
b.	27	10	37
c.	12	7	19
d.	16	11	27
e.	8	6	14
f.	11	5	16
g.	4	3	7

(Since many of the alternatives do not apply to schools and since few of them specified any "other" alternative under (h) above, replies from schools have been omitted from this table.)

THE INSTRUCTORS

Five questions were asked concerning the instructors -- their qualifications, salaries, etc., and the number of professional training programs available to prospective instructors.

1. a. How many mobility instructors do you employ full time? Part time?
   b. What other duties are assigned to your part time mobility instructors? Describe briefly.

	A	B	C	TOTAL
Full time	32	21	3	56
Part time	106	22	31	159

In residential schools the part time mobility instructor is usually a teacher of physical education, academic subjects, or both. In other agencies, 17 "other duties" were mentioned in the replies, the most common being home teacher, rehabilitation counsellor, social service counsellor, case worker and crafts instructor.

2. How many of your mobility instructors are totally blind? Partially sighted? Fully sighted?

	A	B	C	TOTAL
Totally blind	37	3	2	42
Partially sighted	45	10	9	64
Fully sighted	58	29	22	109

3. What are the qualifications of your present mobility instructors?

Fourteen agencies list a bachelor's degree as a qualification of their instructors, four of them specifying the degree in physical education. Thirteen agencies mentioned the master's degree, three specifying the degree in physical education. Nine mentioned specifically the training course at the Veterans Administration Hospital, Hines, Illinois, while three mentioned the workshop of San Francisco State Teachers College. In-service training in general, and experience in work for the blind were each listed by six agencies.

4. What is the salary range of your present mobility instructors?

	A	B	C	ALL AGENCIES COMBINED
Average minimum	$4766.	$4650.	$4446.	$4671.
Average maximum	6248.	5416.	6114.	6023.

5. Do you offer professional training to prospective mobility instructors? If so, describe briefly the content of the training program.

Eleven agencies offer this professional training. The two agencies conducting formal programs in cooperation with an institution of higher learning are St. Paul's Rehabilitation Center in Boston and the Veterans Administration Hospital at Hines, Illinois. The other nine agencies offer an in-service training program.

WHAT IS THE SEEING EYE?

G. William Debetaz

The Seeing Eye is a national organization with the purpose of teaching dogs to guide blind people, teaching blind people how to use the trained dogs and training instructors to do that work. The Seeing Eye was founded in 1929 by Mrs. Harrison Eustis. The dogs used at The Seeing Eye are mostly German Shepherds, Labrador Retrievers, Boxers, and a few other recognized breeds; also some that may not be pure bred but are intelligent enough to take the training and are nice looking. The dogs must be large enough to pull a blind person from danger, if necessary, and must have a coat which is easy for a blind person to keep clean. For these reasons, we are limited in the breeds used for this work. The reason German Shepherds are more suitable is that for generations they have been working dogs with some responsibility, such as caring for sheep. We train males and females - 20% males and 80% females.

The blind people who can utilize the services of The Seeing Eye are between the ages of 16 and 55. They must be in good physical condition in order to be able to take the training and must have both a desire and a need for a dog. We state the age of 16 because we feel it would be unfair to put a dog in a situation in which it will come in contact with other youngsters and be used more as a pet than a working dog. Unless the young person is a fully mature individual, he may not realize the importance of keeping the dog under control for his own safety. There is greater flexibility in considering those in the upper age bracket, as all of us know that some people in their sixties may be in much better physical condition than others in their late forties. Some may become blind in their early sixties having been very active beforehand and certainly should not be denied the privilege of using a guide dog because of their age alone.

The dog training program, which requires three months, begins with 10 days to two weeks of obedience training on our grounds--teaching the dog to "come", "sit", "lie down", "rest" and "fetch". These are the excercises which will be given the dog daily, during training and after master and dog leave the school. They are more or less like Army drills to remind the dog who is master. This is when the master can really enforce his commands, if necessary, without having to worry about his own safety. After the basic obedience work has begun, the dogs are taught harness work. This is done on the streets of Morristown, first by teaching the dog to walk at the regular speed from block to block, stopping for up-and down-curbs and crossing the street in a straight line. After this is learned, they are taken to sections where there are some obstructions and pedestrians on the sidewalk; next they are promoted to traffic work, overhead obstructions, and other more complicated situations. At this stage, the dog is taught intelligent disobedience; in other words, if the master's safety is involved, the dog may not execute the command but use its own judgment in handling a situation. The last two weeks are used for brushing up and polishing details.

All through this process, each dog is tested and rated as any youngster in school by having the instructor, under blindfold, work the dog, with a supervisor following and grading the work. This takes place at least three times during each dog's education.

When a dog qualifies as a guide, it will be turned over to a blind person who will be a member of a class of six or eight people for a period of four weeks at the school. There are generally two or three groups at the school at the same time - each group working with one instructor, generally the one who trained the dogs. The blind people are taught the same way as the dogs by starting on easy, quiet streets of Morristown, moving ahead every few days to more difficult work, so that by the end of the third week, they can navigate all over Morristown, including the railroad station, stores, elevators, and bus transportation. Bear in mind that the first trip the blind person takes with his new dog is out of doors, on quiet but nonetheless actual streets.

Once the student leaves for home, we keep in contact with each one by correspondence, or by visits if a staff member happens to be in the community where the person and dog live. If needed, special checks will be made of the work should any difficulty arise.

In summary, I wish to quote from one of our Seeing Eye graduates a very good statement of the basic ingredients in the ability of a blind person to achieve mobility with a dog:

> "He must understand that he is blind and that his dog can see. This adds up to a human limitation and a canine potentiality. On the other hand, he has the power of reason, while his dog has certain powerfully irrational instincts, and this adds up to a human potentiality and a canine limitation.
>
> Both have the power to love, which alone can make possible the patience, the concentration, and the self-discipline necessary to weld the two-- the man-animal and the dog-animal-- into a corporate unit. Through love they learn to recognize and forgive both their own and each other's limitations and, therefore, to realize their joint potential."*

*Putnam, Peter; THE MIRACLE OF A BLIND MAN AND HIS DOG, The New York Times Magazine

FACTORS IN MOBILITY REHABILITATION WHICH EXPERIENCE HAS PROVEN USEFUL

Loyal E. Apple

Mobility is a term used to describe a teachable technique which enables a blind person to go from place to place on his own. Mobility answers certain basic needs of the blind individual: it alleviates bodily tensions, it enables him to be himself, and to be accepted socially, vocationally, or personally. It also answers the need of the blind individual to emancipate himself from the influence of the training situations and to match his abilities against the demands of the community.

In order to set the frame of reference for a discussion of factors in mobility rehabilitation it would be well to outline where this experience has taken place, with whom and by whom.

The WHERE is the Central Blind Rehabilitation Section at the Veterans Administration Hospital, Hines, Illinois. This program was established in 1948 as a development of the military service program for the war blind of this country.

The experience of the staff has been with a group of about 1,000 individuals characterized as follows: male, adult, considered to be fit physical specimens when inducted into military service, blinded at an age of eighteen or greater and have applied for the program.

This group varies in age from eighteen to seventy-nine. The men now at Hines average 33 years of age. They range from men whose only disability is blindness to men who have one or more additional disabilities.

These disabilities range from partial deafness to flat feet, from brain damage to ulcers and amputations. They vary widely in educational, vocational and social background. The Section provides a controlled environment whose activities and facilities are directed toward the benefit and positive reorganization of the blinded veteran. Here mobility is an essential part of the total program. As one of the necessary therapeutic disciplines it is interrelated with and supported by them. Pre-vocational shop therapy involving the use of hand power tools, adaptive devices, communication involving the use of braille, typewriting, handwriting, and electronic recording instruments, counseling, socio-recreational activities and athletics, make up the other phases of the program.

By WHOM was this experience gathered? All of the mobility personnel at Hines are physical education majors, who have spent one year working with patients having disabilities other than blindness before coming to the program. They were selected for personality and ability and given intensive and continuing training in this discipline. They spent about twelve weeks in learning the techniques from the bottom up while wearing a blindfold, with a comparable period of time being spent in observing trained therapists at work, and another three to six months practicing their discipline under supervision.

We require these men to be trained under the blindfold because it is important that they have confidence in and receive satisfaction with the mobility techniques which they will teach.

It is highly important that the mobility instructors have a full comprehension of the basic physical facts of blindness.

The mobility instructor, knowing that he can cope with the physical factors involved in blindness, operates from a platform of knowledge and strength and can more confidently communicate his knowledge of the cane technique and its adjunctive travel techniques to blinded individuals.

The first factor, then, is the validation of techniques in the experience of the persons responsible for teaching them. There is no replacement for properly trained personnel who are qualified to do what they can enjoy doing best, teach. Technical knowledge which has been validated in experience in the hands of persons skilled in interpersonal relationships makes for properly weighed and well-timed communications.

The second factor is the pacing of the mobility experiences of the blind individual. The blind individual must begin early to move about on his own and instruction is planned so that this will happen. Greater varieties of experience and wider ranges of movement must be provided in a progressive fashion. At no time should the pace of the program be beyond the reach of the blinded individual so as to make him feel grossly inadequate. At first the individual will perform tasks because the instructor says that he is able to, but with successful experiences, he will do them because he wants to. The first mobility and orientation experiences of the blinded veteran are in his room and from there he moves to his corridor and adjacent parts of the Section. He then can travel throughout the hospital and from there to the outdoors, on the hospital grounds. The environment has been fairly well controlled up to this point and he has had an opportunity to establish a basic trust in the techniques, the staff, and himself. He then moves into an uncontrolled, but uncongested urban environment and then to a moderately congested business area where he gains command of techniques for handling a wide variety of environmental situations before advancing to highly congested areas such as the "Loop" section of Chicago. His travel situations have become progressively more complex, while not necessarily becoming more difficult for him to cope with. Since he does not advance to new situations until he has successfully accomplished the task at hand, he is better able to form a realistic self-appraisal of his potentials.

By building his mobility skills brick by brick the blinded individual at the same time develops a positive attitude toward himself, others and his environment.

A very strong factor in mobility rehabilitation is the provision of all instruction on a one-to-one ratio. This kind of an arrangement provides an opportunity for both the blinded individual and the instructor to do their best allowing for the exploration of sensitive areas, timing of presentation of new material and safety and correction. In addition, it takes into account the fact that the blinded individual cannot observe and imitate as can the sighted individual.

Another factor in this area of rehabilitation is the alert non-intervention in the judgement and problem-solving processes of the blinded person. Blind trainees should be allowed to utilize all of their available resources for the solving of a mobility problem before solution is offered by the instructor. He must be alert that undue frustration does not occur or physical harm result.

These factors are applied alike to the development of psycho-motor skills in the use of the long cane, auditory discrimination, tactual awareness, kinesthetic awareness, and olfactory awareness. Emphasis is maintained on function in all spheres throughout the program's eighteen weeks or so.

Stress is laid on the utilization of auditory cues, tactual cues, etc., where they are found and under the conditions in which they occur. Space does not permit a discussion of the development of the use of these additional senses but it will suffice to say that the blinded individual is encouraged to move from the use of gross cues to more complex discrimination under adverse conditions.

We believe strongly that the blinded individual should be viewed as a whole person, who, if properly motivated, can reach the outer limits of the combined performance of his physical, mental, and sensory being. The willingness of the individual to accept, trust, and learn functions is of critical importance for it will determine the actual extent to which any technique for mobility will be used.

ENGINEERING ANALYSIS OF CANE INFORMATION ACQUISITION

Dr. Thomas B. Sheridan

Using a cane to acquire information about the environment is similar to sounding the depth of the ocean or looking for oil under the earth's surface. All of these tasks can be thought of as parts of the more general problem of pattern recognition. Sensing with a cane differs however from other kinds of human perception in that the information intake is much smaller and is sought by a discrete sampling technique. Thus the cane might be said to have important built-in constraints.

How is the cane used and what aspects of the environment can be measured with the cane? The cane itself is a simple mechanism, usually a hollow metal tube having a crook at one end and a more or less durable tip of metal or some other material on the other end. In probing the environment, the man pushes on the cane and the cane pushes directly back on the man. In coordinating his arm motion with this experience of constraint, he thus begins to sample the geometry of the environment. There are further cues arising from the impedance, if you will, to the pokes or taps of the cane. The environment has a spring characteristic, it may have a viscous characteristic (in snow or sand, for example), it may even have a kind of inertial characteristic. Furthermore, there are forced vibrations transmitted through the shaft when the cane is dragged along a surface, and these will differ depending on the material of the surface.

Both tapping the cane and sliding it along provide tactile, kinesthetic and vibratory cues which are transmitted to the user through the shaft of the cane. In addition, there are auditory signals coming from the environment itself. The simply structured cane, then, provides the sentient, intelligent user with several kinds of information, and is perhaps best considered an extension of a sense organ. The question is how a man can best use the cane to gain the most information about those aspects of the environment in which he is interested.

Unfortunately the problem is not simply one of physics and physiology. A man could easily obtain a great deal of information by flailing the cane vigorously about in random motion. The reason he does not do so is that he would incur a social penalty, so to speak, that he is not willing to pay. Thus the problem takes on a larger social aspect and involves the total image of the blind traveller in society. There must be some compromise between the maximum functional capacities of the man and cane and the unfortunate popular image that might be engendered if he were to utilize the cane to its fullest.

Other devices than the cane could be devised to gain information about the environment through physical contact, and some of them might even be better than the cane in some respects. A mechanical robot dog might be made to run in front of the man, seeking out the characteristics of the environment and relaying the information back to him. Or a swarm of insects might fly in front of him, creating a sort of screen. Or he might simply carry a large piece of cardboard or an umbrella in front of him. For certain purposes each of these might be superior to a cane. But the social penalty attendant on the use of such devices would be prohibitive. This balancing of information-gathering capacity against potential social disfavor is a difficult problem and one which I will not attempt to answer here.

Another fundamental question with respect to the use of the cane is, what effect does motor activity have on sensation? What is the difference between active participation in a sensory situation and passively observing it? Professor Richard Held at Brandeis University has been investigating this problem and has published several papers on the subject. He uses kittens which are restrained in harnesses suspended from a rotating beam. One kitten is permitted to walk around the cylindrical container, but the kitten on the other end of the beam is suspended so that his feet can not touch the floor. Thus he has the same visual experience and also experiences the same locomotion, but only passively. He does not have the accompanying kinesthetic experience. After a few weeks the kittens are removed. If you take the kitten which has been actively participating in the sensory situation and carry him toward the edge of a table he will put out a paw to defend himself. The other kitten will allow his nose to bump against the object, making no attempt whatever to protect himself. He has not had the benefit of kinesthetic cues in his learning. This should be interesting research to follow in terms of the problem the blind traveller faces in mapping out the environment with the aid principally of kinesthetic and auditory cues.

Let me describe now some of our initial experiments with the cane, several of which were conducted by Leonard Potash in preparation for his master's thesis "Correlates of the Tactual and Kinesthetic Stimuli in the Blind Man's Cane" (M.I.T. June, 1961).

One experiment was concerned with selectively filtering various kinds of sensory information. In one case, hearing was masked; in another, the subject used a cane in which a universal joint had been inserted so as to eliminate certain cues about the geometry of the object; and in a third case the vibrations in the shaft of the cane were damped by cutting a cane in half and inserting a piece of rubber tubing between the two parts. The principal thing we learned was that subjects can be quite inventive, adjusting their techniques to compensate for the cues that were lacking.

A second experiment involved measuring the vibratory information from the cane when different objects and materials were probed. The vibratory patterns differ and also damp differently depending on the material. The cane however has a natural frequency which predominates and any other frequencies in the vibration are superimposed on that natural resonance. In this way it is like the problem of distinguishing between human voices which have more or less the same formants or natural resonances. Obtaining useful measurable differential signals from the vibration of a cane proved difficult and conventional strain-gage bridge techniques did not appear sensitive enough to render the different patterns meaningful. We plan further efforts to distinguish the characteristics of cane vibration when different materials are probed or tapped.

The third experiment was a measurement of kinesthetic discrimination. Blindfolded subjects' canes were guided so as to touch two points, one to their left and one to their right, 24 inches apart. They were then asked to bisect this distance and touch the mid-point with the cane. The same experiment was repeated, aligning the two points along the depth axis, one near and the other farther away. In each case, the standard deviation of the errors was about 10% of the total sweep distance.

The fourth experiment measured the cane user's ability to discriminate between various mechanical impedance characteristics on the basis of a transient "probe" or poke with the cane. A cantilever spring was set up in such a way that the blindfolded subject could probe the same place twice in rapid succession. There were three parts to the experiment. In the first part, the force at the stop or strain limit was held constant and the displacement to the stop was varied from the first to the second probe. The subject stated which displacement was greater. In the second part, the displacement was held constant and the force level was varied. The subject judged which force was greater. In the third case, the stop was removed and the spring constant was varied from the first to the second probe and the subject could push as hard as he pleased. He was required to state which was stiffer.

Ordinary psychophysical techniques of threshold measurement were employed in this experiment. The "just noticeable differences" were obtained by introducing, at random, increments of change amounting to plus or minus 2,4,8,16 or 32% of the reference level.

The jnd was taken as the level at which subjects averaged 75% correct judgments. The experiment was performed at different reference levels of displacement and spring constant at both one pound and ten pounds net force at the strain limit in compression probing and 0.1 pound in lateral probing. The data are summarized in Figures 1,2 and 3 as jnd percent vs. reference level. One may conclude from these data that the cane user can resolve 5-10% differences in displacement and/or force in compressive probing, but is not quite as good in discriminating different spring constants. At an axial force level of ten pounds and also in probing laterally, the cane bends and his environmental discriminations are impaired by the elasticity of the cane itself.

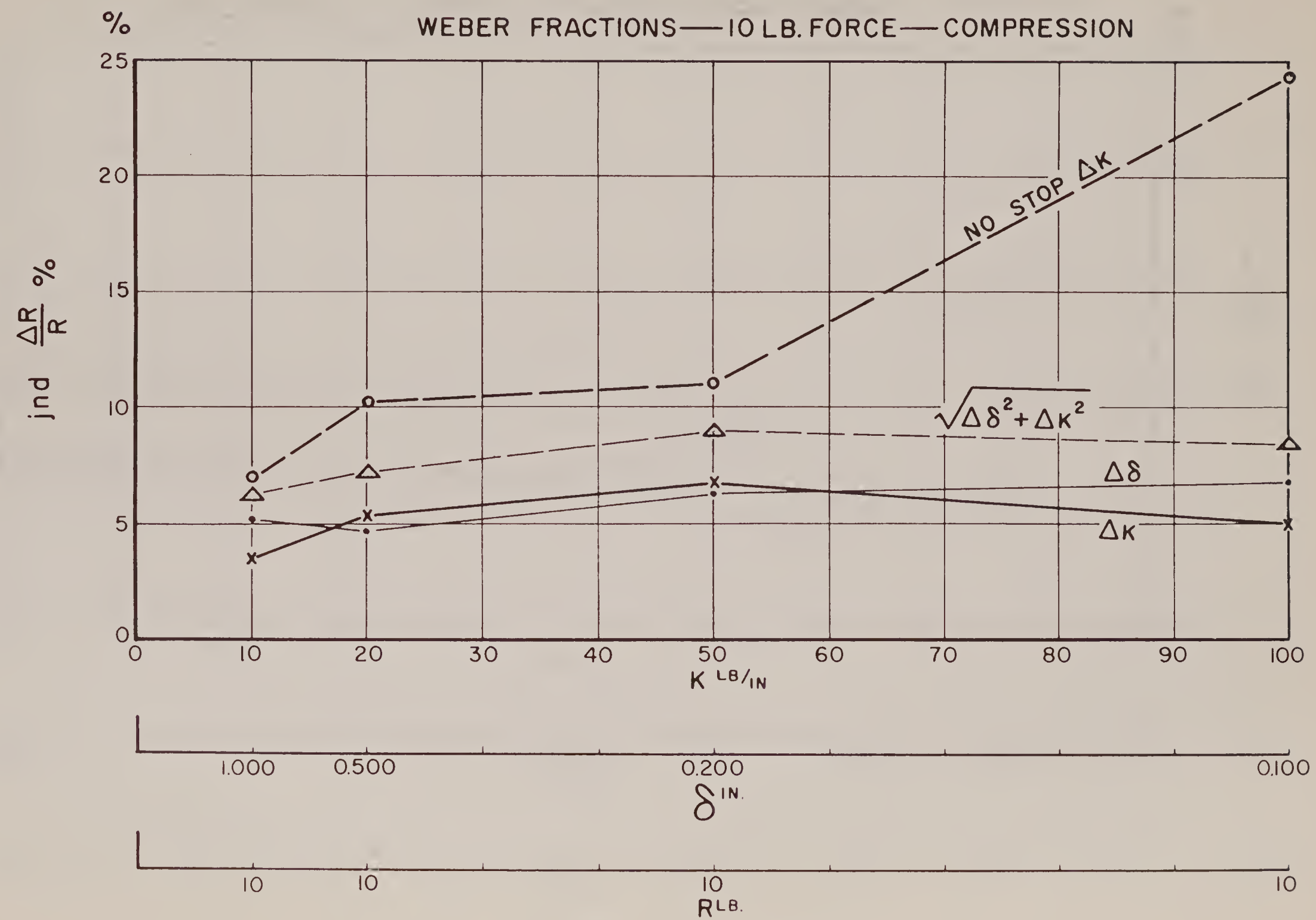

WEBER FRACTIONS—10 LB. FORCE—COMPRESSION
%
jnd $\frac{\Delta R}{R}$ %
25
20
15
10
5
0
NO STOP ΔK
$\sqrt{\Delta\delta^2+\Delta K^2}$
Δδ
ΔK
0
10
20
30
40
50
60
70
80
90
100
K LB/IN
1.000
0.500
0.200
0.100
δ IN.
10
10
10
10
R LB.

Figure 1.

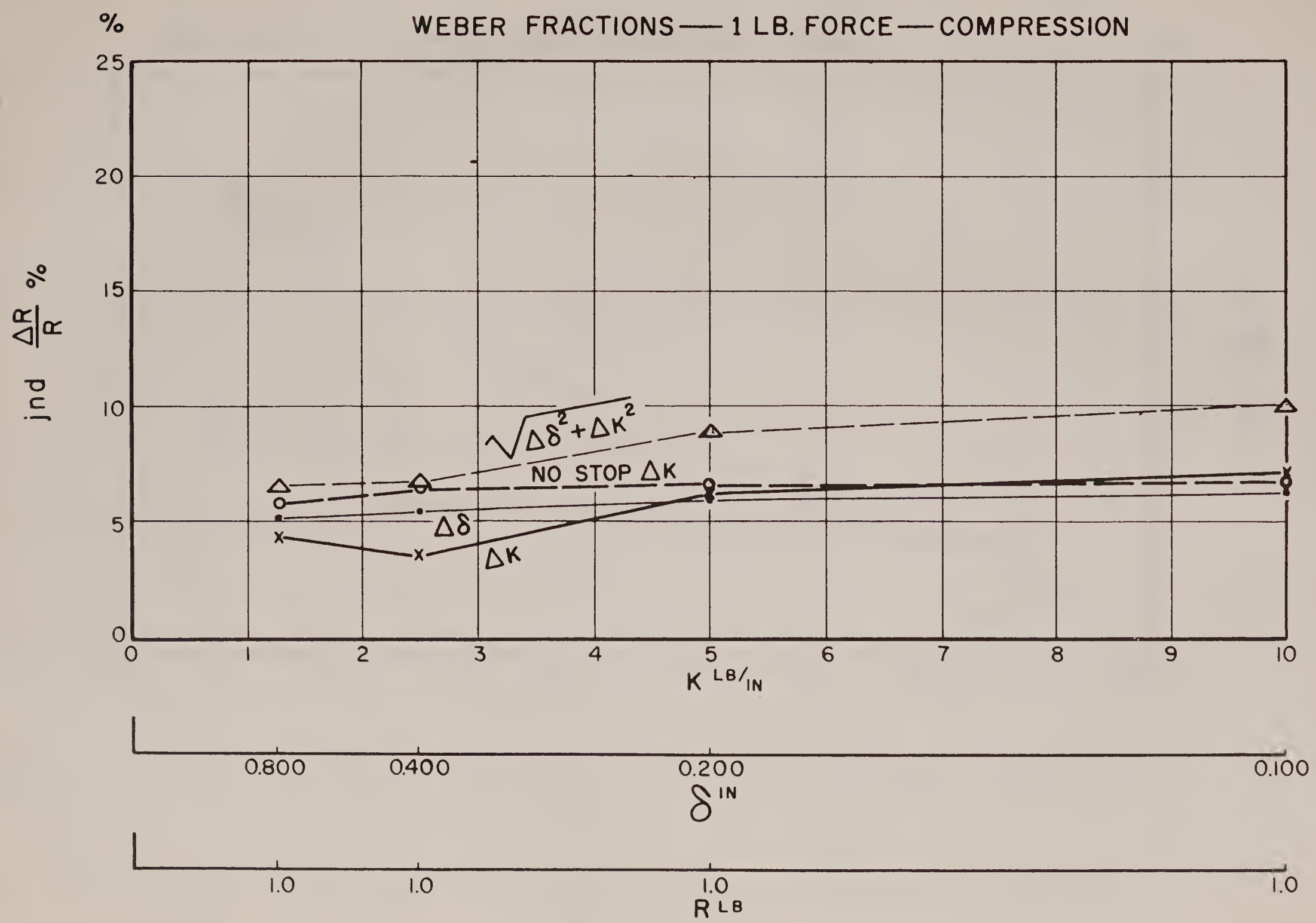

WEBER FRACTIONS — 1 LB. FORCE — COMPRESSION
%
jnd ΔR/R %
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
K LB/IN
√(Δδ² + ΔK²)
NO STOP ΔK
Δδ
ΔK
0.800
0.400
0.200
0.100
δ IN
1.0
1.0
1.0
1.0
R LB

Figure 2.

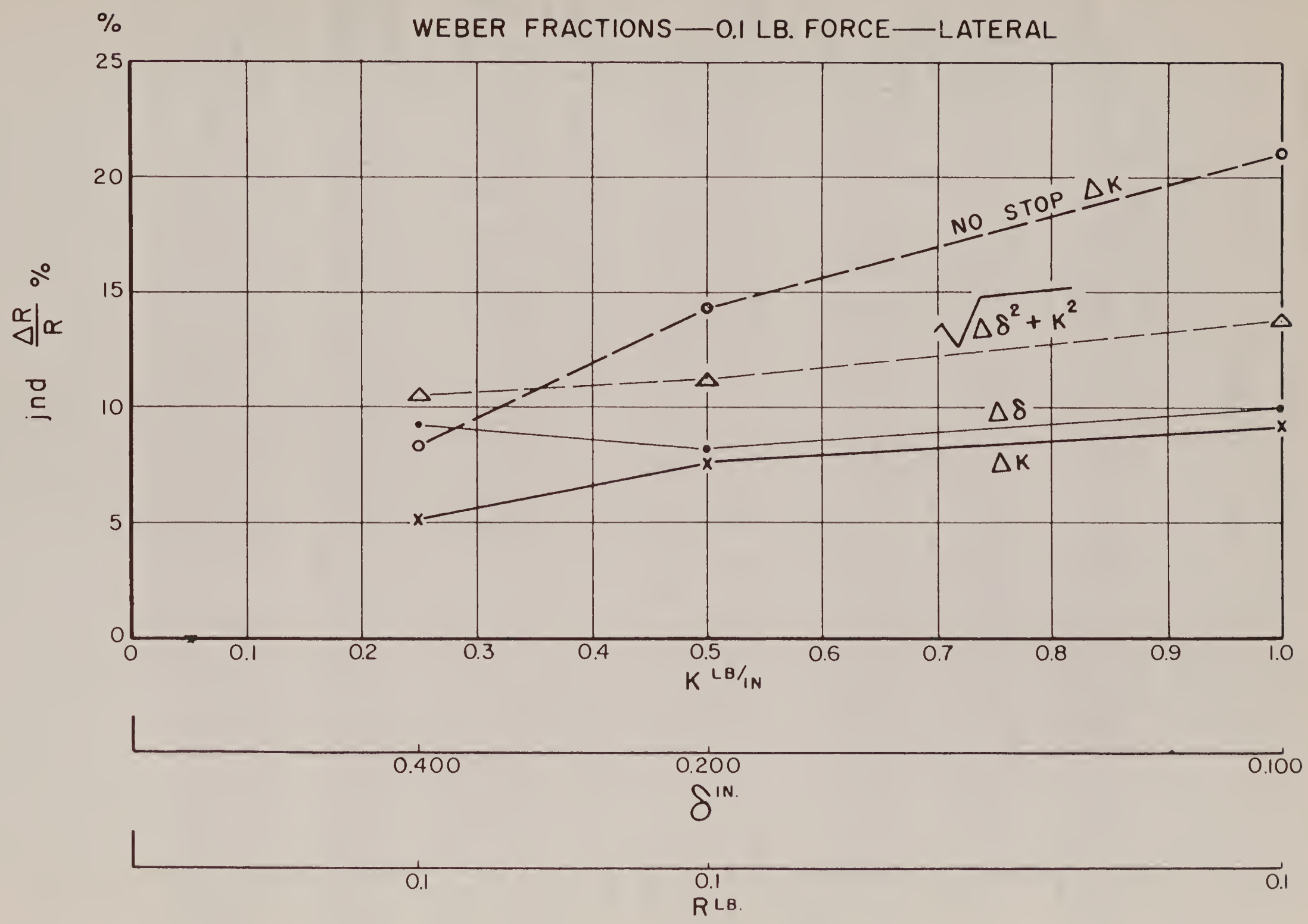

WEBER FRACTIONS—0.1 LB. FORCE—LATERAL
%
jnd $\frac{\Delta R}{R}$ %
25
20
15
10
5
0
NO STOP ΔK
$\sqrt{\Delta\delta^2 + K^2}$
Δδ
ΔK
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
K LB/IN
0.400
0.200
0.100
δ IN.
0.1
0.1
0.1
R LB.

Figure 3.

SONIC OBJECT SENSING

DR. A. W. MILLS

We live in an acoustical "hall of mirrors". Many objects in our environment have surfaces that reflect most of the sound that strikes them. The notion that a blind person might utilize these echoes to aid him in getting about has quite a long history.

It was probably Diderot who first suggested it. In observing blind persons traveling about the city of Paris, he noted that they were able to discriminate easily between a through street and a cul-de-sac, and suggested that they were able to do this by somehow sensing the movements of the air. Whether or not he was actually referring to sound waves is not clear. Unfortunately for Diderot, the notion proved quite unpopular with the French authorities and he spent three months in prison for publishing this novel hypothesis. Blind people were at that time supposed to navigate by means of supernatural powers.

A number of hypotheses were entertained over the years concerning "facial vision" as it came to be known, and a number of inconclusive experiments performed. The first thorough experiments were performed at Cornell University by Karl Dallenbach and several of his graduate students. They eventually concluded that hearing is the principal basis of facial vision.

Their experiments were conducted in a corridor about 60 feet long in which a 4' x 5' screen was placed in one of a number of positions over a range of about 30 feet. Blindfolded persons, both blind and sighted, were then asked to walk down the corridor and to report twice, once when they became aware of the presence of the screen, and again when they thought they were about to bump into it. By and large, the subjects did quite well, although the ability varied somewhat from person to person.

Dallenbach then decided to remove the sound of the subjects' own footsteps by covering the wooden floor with a double layer of carpeting and asking subjects to remove their shoes. They were still able to detect the screen but not nearly as well. Subjects occasionally bumped into it.

The hypothesis of facial vision, however, was still untested, since the subjects' faces and hands were still exposed. Another experiment was conducted with the subjects wearing veil and gloves to shield them from air currents. Even this made no difference. They could still detect the obstacle.

Dallenbach then decided to try earplugs. He thought that with these plugs he was getting about 65 db of attenuation, but in view of more recent work it seems reasonable to suppose that he got only about 20 db. Much more than 20 db of attenuation is difficult to obtain with earplugs; the plugs have a way of vibrating in the ear, and sound has a way of getting in through the bone. But they were good enough for this experiment. Subjects wearing the earplugs walked straight into the barrier.

Still Dallenbach was not satisfied. Perhaps, as William James had suggested, it was not the hearing apparatus itself but only the ear drum that was involved. He then decided to remove the subject to another room, equip him with earphones, and allow another man to walk down the corridor wearing a microphone. Subjects could still detect the obstacle, although not quite as well as when they were actually there. It would seem then that hearing is the essential factor.

But what if the man actually walking the corridor was unconsciously cheating for the listener by slowing down at the right places, thereby increasing the density of guesses at those places? They decided to install an impersonal walker, a trolley which carried the microphone down the corridor by remote control. Since a trolley does not make footsteps, they also attached a loudspeaker to the trolley over which they broadcast sine waves of various frequencies. They found that if the frequency of the sine waves was low, listeners would allow the trolley to bump into the obstacle. Frequencies of about 10,000 cps enabled listeners to detect the obstacle almost as well as when they were there in person. Frequencies between 8,000 and 10,000 cps were not as good, and frequencies of less than 8,000 cps were very poor indeed. In addition to sine waves, they tried using white noise over the loudspeaker and found this worked even better.

Another experiment was performed using naturally deaf subjects, some sighted and some blind. The hypothesis was that the naturally deaf should be unable to detect the obstacle and unable to learn to detect it. The hypothesis was affirmed decisively in the case of the sighted deaf. The deaf-blind, however, are well known for their cleverness in detecting odors, temperature changes, air currents, etc. In outdoor experiments for example, the masonite screen, heated by the sun, gave off a slight odor that was detected by the deaf-blind subjects. Consequently Dallenbach and his co-workers concluded that hearing is a sufficient condition for facial vision, but were not willing to conclude that it is also a necessary condition.

With respect to the signals used, they concluded that continuous sounds are just as good as discontinuous sounds. This conclusion is perhaps unfortunate since they took footsteps as their model of discontinuous sound. They might for example have tried pulses of white noise rather than continuous noise, and short bursts of pure tone rather than continuous sine waves.

Dallenbach's subjects reported that they detected the obstacles by a "sharpening" or slight rise in pitch of the echo. Since the trolley was indeed moving relative to the screen, they suggested that the Doppler effect was responsible. I have since done some similar experiments, however, and find that this apparent rise in pitch is not really dependent on the relative motion between reflector and listener. The Doppler effect is probably not essential.

In the time remaining let me discuss a pilot experiment which we conducted at Tufts University in 1961. We mounted a loudspeaker on the chest of a blindfolded listener. He was free to turn toward a reflecting target located at one of two places 45 degrees apart and either 24 feet or 40 feet away from him. We used a variety of pulsed sounds: sine waves; high passed, low passed and unfiltered noise; and some pseudo-bat sounds, i.e. sounds that are frequency modulated so that their frequency is a decreasing function of time. The targets were 18" x 36" military "silhouettes". The subject was given about four pulses in one trial during which he could point the speaker wherever he pleased. After each trial he indicated where he thought the target stood.

We had planned to evaluate the utility of different kinds of sounds for echolocation by counting the subjects' mistakes, but they rarely made any. Even at 40 feet, the flat cardboard target was too easy. We then set out a real man as target. This was more difficult, but after a few hours of practice even the man proved to be too good a reflector. Evidently we needed a small boy. Practice seemed to render the task easier and easier.

At the 24 foot range subjects heard a sort of sharpening in the tone, probably similar to what Dallenbach's subjects heard. This rise in pitch remains somewhat mysterious. We used two pulse lengths, 32 ms and 64 ms. Although in the case of the 64 ms pulse, this sharpening could be due to a direct physical interaction, when the pulse was 32 ms long, the sound reaching the ears directly from the loudspeaker would have been over before the echo returned. At 40 feet, the subjective experience was somewhat different. After a little practice the subjects simply reported the presence of a man. They perceived the target directly without any intervening introspection about what was going on in their ears.

The subjects' performance was consistently better when a wide band width signal was used and he was much more confident of his judgments. When he was right he knew he was right. Low freqnencies did not seem to work as well as high frequencies. This is easy to understand since the target was fairly small, and you get good echoes only from objects whose linear dimensions are nearly as great as the wave length of the sound.

The possibilities of acoustic orientation for man have only begun to be explored. After a good many years of diligent investigations we know quite a bit about how people localize sounds -- in an anechoic chamber -- but only recently has the perception of echoes come under similar scrutiny. Further understanding does not depend primarily upon the solution of any technical problems, but upon the interest of psychoacoustic investigators and their sources of financial support.

CURRENT ACTIVITY IN AN ECHO ENHANCEMENT STUDY

Dr. Howard A. Baldwin

The following information is presented as a short summary of the research undertaken under RG-2556 sponsored by the National Institutes of Health in which we are concerned with enhancement of the natural ability of the human to echo-locate. Some of the early work in echo enhancement has been discussed by Dr. Mills so I will not attempt to do more than highlight the references which seem to be of primary interest to our study.

In 1955 Dr. Ivo Kohler undertook a study which he entitled "Orientation by Aural Clues" in which he tested some 255 sighted and blind subjects to obtain measurements of their obstacle avoidance sense. He was concerned with both naturally acquired ability, and with the evaluation of the click generator device. This device generated audio frequencies ranging from 1000 and 4000 cycles per second to match the range of maximum acuity in the human ear. His results may be summarized briefly as follows: Of 217 subjects 107 immediately showed useful obstacle reaction. The average maximum distance at which the standard test obstacle could be recognized was 25cm, and in some cases subjects could reliably indicate the presence of the test obstacle at 100cm or more. All of the subjects tested were aware of the presence of the object at some distance before their faces. Using the click generator developed by Kohler, the average distance became 84cm and a maximum range of 120cm was possible for some individuals. Dr. Kohler reviews effect of training and studies of tactile sensation that I will not attempt to include here. He arrived at the conclusion that some 2.6% of a population, based on the number of subjects he tested, may be expected to be gifted in obstacle sensing. He found no correlation with auditory test scores as determined on a standard audiometer. He did find correlation with the subjects ability to discriminate small differences in sound intensity, however. The click generator, used for enhancement of echoes, had a number of limitations due to the frequency range in which it operated. The long wave lengths provide poor definition for small objects or objects set at an angle which did not return an echo to the subject. Our approach has been to use ultrasonic frequencies in the range from 20,000 to 100,000 cycles in order to provide definition in the returning echo. Furthermore, we have borrowed techniques from the analysis of animal echo location systems, such as those described by Griffin, which indicate that rather broad band signals are generated in the more precise pulse echo location systems. A device (Fig. 1.) has been constructed which will generate a pulse of frequency which can be varied in time length from 2 to 40 msec. The device has the ability to sweep the carrier frequency during this time over a full octave, that is, from 20 to 40kc, 40 to 80kc, or 60 to 120kc. Bursts of ultrasonic energy are then propagated in air by the use of a non-resonant transducer. In particular, we have found the Electro-Voice, Model T-3500 IONOVAC Super High-Frequency Driver ideally suited to this application. This unit is operated by modulation of an ion

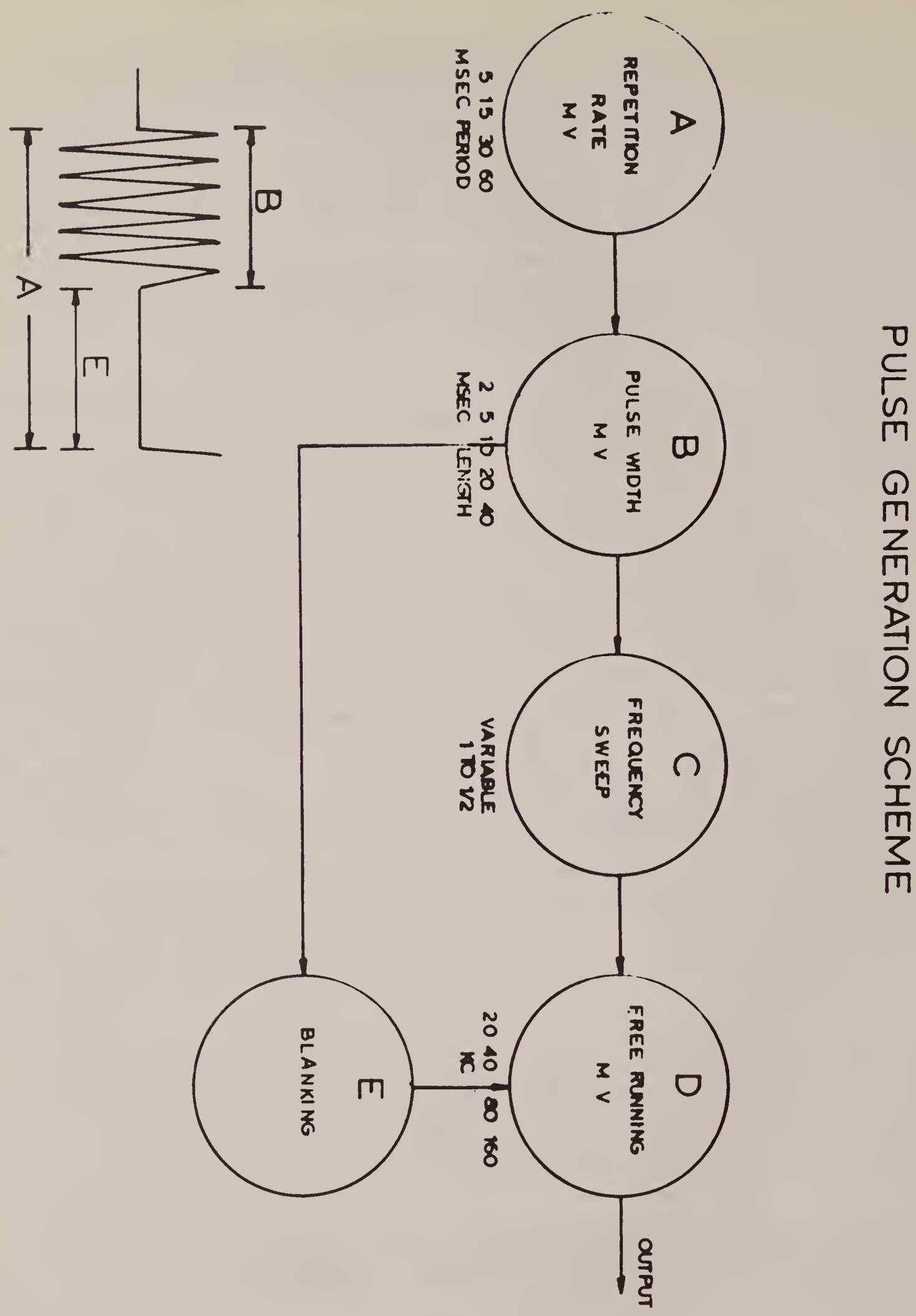

PULSE GENERATION SCHEME
A
REPETITION RATE M V
5 15 30 60 MSEC PERIOD
B
PULSE WIDTH M V
2 5 10 20 40 MSEC LENGTH
C
FREQUENCY SWEEP
VARIABLE 1 TO 1/2
D
FREE RUNNING M V
20 40 80 160 KC
OUTPUT
E
BLANKING
B
E
A

Figure 1

stream created at the base of a small cone-like quartz cell. This, in effect, provides a speaker whose voice coil has almost zero mass, and the manufacturer claims a response from 3500 cycles to 40,000 cycles within plus or minus 4db. Although we have not yet undertaken calibration above 40kc, we expect that considerable signal energy will be propagated above this frequency. At the present time, echoes are received with one of the Massa crystal microphones, and are displayed on an oscilloscope. In the near future we will undertake investigation of the change in the envelope of energy from echos upon being reflected by a variety of common material surfaces. After analyzing the information relating to physical characteristics of targets or obstacles we will then undertake the design of a detector system to extract the information from the modulation envelope of the echo and make it available in the audio range. Band width compression may or may not be required.

We are also curious about the ability of the human to conceptualize or visualize the structure or properties of an obstacle from sound energy. This particular area of investigation is extremely difficult, and the results obtained thus far, while interesting, are not to be interpreted in any sense as controlled experimental information of scientific value. As to the question, "Is it possible to stimulate an image from auditory clues?", some work has been done on synesthesial effects and Karwoski and Odbert published a monograph some time ago entitled "Color Music". They were able to elicit color music experiences in approximately one of four subjects. We undertook a brief experiment to ascertain whether such an effect could be produced by sound energy of various wide frequency band widths. Our experiments involved some 15 naive, volunteer subject students who happened to be passing the laboratory at convenient times. After preliminary screening for gross auditory defects, subjects were asked to sit in an acoustically damped room approximately 4'x7'x8'. Two spark gap buzzers in the upper corners of the room were operated at random by the experimenter, and subjects were asked to describe any sensory impression which they experienced, that is, they were asked to relate any sensations of sound, sight, taste or touch. The room was darkened for the test, and the responses of the subjects were recorded on tape and transcriptions from the tapes are quoted below. Because the buzzers utilized an electric arc, there was a small amount of light present at the sound source. The subjects were instructed, therefore, to look at the floor and in those cases in which the subject reported sensation of light during the test he was subsequently shown the light given off by the arc. In no case did the subject report a light from the arc as being similar to the visual effect experienced. Five of the 15 subjects responded of which four claimed to experience visual sensation. Before quoting from some of the recorded data, I would like to emphasize we have every possibility in this preliminary study of generating a response by providing an environment in which the subject is <u>expected</u> to have some type of sensation. Jackson and Kelly at the University of Michigan in a paper entitled, "A Study of the Role of Suggestion in Research on Sensory Deprivation" to be submitted for publication, were able to elicit unusual, interesting, and even dramatic or bizarre subjective experiences among subjects who were led to believe that such responses were to be expected.

With this word of caution the following are extracts of subject responses:

SUBJECT M.M.

> "Sound; sound. I seem to see a light after the sound, its a round circle. Sound; sound; sound and I saw a light. It was just a flash. Sound; sound; sound; sound; sound, but it seems to be from a different source. Sound; sound; sound; sound; sound; sound; sound; light. It was just a dot, straight down (in from), a steady dot right after the sound. Sound; light; it looked like a line moving; started half way from the baseboard and moved up. (it was) about 9 to 12 inches wide. Sound; sound; light after the sound. Light, a large circle moving up. White light, a circle that is diminishing. Light, still a circle. Light, it seems to stay; seems to diminish with the sound. The sound makes it smaller. It's fading now....." etc. etc.

/Ed. Note: Quotations from three other subjects were included by the author./

We have continued some investigation of cross-modal effects in a subsequent study and also have undertaken some measurements of ability to discriminate changes in intensity of white noise. Actually for the purposes of echo enhancement the existence of synesthesial effects due to the sound of an echo is not essential. If we can provide in the echo sufficient information about the properties of an obstacle we will be quite content to undertake a training program--even an extensive one.

SIGNAL DETECTION IN NOISE - REMARKS ON DESIGN CONSIDERATIONS FOR AUDITORY TRAVEL AIDS FOR THE BLIND

Nathaniel Durlach and Irwin Pollack

A. Introduction

Although the subject of this paper is "Signal Detection in Noise" (a subject suggested by John Dupress of the American Foundation for the Blind), we feel that due to the wide variety of disciplines involved in the mobility research effort, it would be inappropriate to immediately delve into a technical discussion of this subject without first putting it in a proper context. We will attempt to do this by considering the distinction between the acquisition of information and the display of information and by considering the general question of interference, of which noise is a special case. It will then be assumed that the display is to be an auditory one and some general remarks will be made about auditory displays. After this, we will consider the question of signal detection in noise for the special case of the human auditory system.

B. The Pre-Display Problem Versus the Display Problem

For certain purposes, it is useful to divide the task of designing a travel aid into two sub-tasks: (a) The task of designing a system to acquire the necessary information on the environment (the pre-display problem); (b) The task of designing a display by which the human observer can make use of this information (the display problem). In general, the research efforts required to solve these two problems will be radically different. To solve the first problem, a problem which is independent of the characteristics of the human observer, one should make use of the recent advances in sensory acquisition systems (both in theory and in "hardware") achieved in the field of communications engineering. To solve the second problem, one should make use of the results obtained in the field of human sensory behavior.

The relative magnitude of these two problems will depend on the point in the data processing continuum at which the information is displayed, i.e., the point at which the observer takes over the data processing himself. At one end of this continuum, the output of the sensor system (after appropriate intermediate processing) will be fed to a series of decision circuits and only the outputs of these decision circuits will be displayed to the human observer.

At the other end, the output of the sensor system will be fed directly to the observer with little or no processing of information between the sensor and the observer. Clearly, whereas in the first case, the pre-display problem will be relatively complicated and the display problem will be relatively simple, in the second case, the pre-display problem will be relatively simple and the display problem will be relatively complicated.

C. Classification of Interference

Independent of where the human observer takes over the data processing, in considering the signal detection problem, it is useful to distinguish between three categories of interference: (a) internally generated noise; (b) externally generated noise; (c) clutter. Internally generated noise refers to interference generated by the sensing system itself, externally generated noise to interference generated by the environment outside the sensing system, and clutter to unwanted echoes. By definition, clutter can exist only if the system is active rather than passive. Moreover, even in the active case, whether or not there will be a clutter problem will depend on the specific function for which the system is designed. If one desires a complete map of the environment, then there will be no such thing as an unwanted echo; all echoes will contain pertinent information. However, if there are certain elements in the environment which are of no concern to the observer, and the echoes from these elements are relatively strong, then the observer may not be able to identify the echoes from the elements of interest even though these echoes are much stronger than the interfering noise. Externally generated signals will almost always be a problem in the active case and may or may not be a problem in the passive case, depending upon whether or not the signals contain useful information.

One important difference between the noise problem and the clutter problem (assuming the system is active) is that the clutter interference, unlike the noise interference, cannot be reduced by increasing the transmitted energy; the signal-to-clutter ratio will remain the same. On the other hand, since the clutter signal represents an echo from a well defined target with definite boundaries in range, angle and velocity, it may be possible to resolve the target and clutter signals and, subsequently, to identify and suppress the clutter signal.

Assuming that only the output of decision circuitry is to be displayed, the problem of minimizing the effects of interference for a travel aid is, in theory, merely a special case of the general interference problem studied by communications engineers and the results in this field are now quite extensive. For example, assuming that the statistical characteristics of the interfering noise are sufficiently well-behaved and that the values of the various types of decision errors have been decided upon in advance, it is possible to compute mathematically the optimum data processing design. In practice, however, especially for a sensory aid which is intended to be used in a wide variety of circumstances, the statistical characteristics of the interference are likely to be quite different than those usually considered. Thus, one must be careful not to apply these results indiscriminately.

D. Auditory Displays

If only the output of decision circuitry is to be displayed, the set of all possible outputs of the display will be relatively small and these outputs can be decided upon in advance. Thus, in designing the system, the engineer can employ a relatively small set of pre-recorded signals for the display and the question of what signals should be used for this purpose can be solved fairly simply. For example, one might use a set of pre-recorded speech signals and attempt to simulate certain aspects of the verbal output of a sighted companion. If, however, the information is fed directly to the listener and the listener himself must process the data, then the signal selection problem for the display becomes much more complicated. One must begin to ask questions about how the listener's response varies as a function of signal intensity, duration, frequency composition, etc. An important fact which needs to be considered when constructing such a display is that the human listener, although extremely poor in his ability to identify signals presented in isolation, is extremely good at identifying small changes from some stable reference condition. Furthermore, it is known that the human listener can respond to many variables in sequence, if not in pattern, provided that the demands are not too great with respect to any one of these variables. (The experience of the "Flybar" study of the Psychoacoustics Lab in World War II may be instructive here for they demonstrated that a "Link Trainer" could be flown on the basis of coded auditory signals alone.)

In general, in constructing an auditory display, one must be extremely careful not to overburden the listener by imposing the need for making fine distinctions with respect to any single coded variable. Either one must use several variables, or the information must be coded into speech, or the coding must be effected by making use of changes from some set of reference conditions.

E. Human Auditory Detection of Signals in Noise

In deciding where in the data processing continuum the human observer should take over, it is instructive to consider how the human observer compares to the mathematically ideal observer. An important finding in this area is that the detection performance of the human tends to fall further below that of the ideal as the parameters of the signal to be detected are specified more completely. For example, if the problem consists of detecting a noise signal above a broadband noise background, the human approaches the ideal rather closely; however, if the signal consists of a pulsed tone of specified duration, time of occurrence, frequency and onset phase, the human falls way below the ideal. In other words, the human observer does not appear to be capable of making full use of all available a priori information.

One particular defect of the human auditory system is that it is only partially frequency selective. Ideally, a system should be capable of filtering out all frequencies not occurring in the signal spectrum. For a given signal frequency the human is capable of filtering out only those frequencies outside a given interval (the so-called "critical band") around the signal frequency. This band appears to be of the order of 100 cps below 1000 cps and increases rapidly with frequency at frequencies much above 1000 cps. Similarly, if the human is trying to detect a pulsed tone, the benefits of increasing the pulse duration decrease as the duration is increased and become substantially smaller than the benefits which would be derived by an ideal system for durations longer than 100 ms. In other words, the integration is imperfect for long pulse lengths. If, in addition to detecting the presence of a signal, one is also attempting to identify it and discriminate between a variety of possible signals, the benefits of increasing the signal duration will continue for longer durations. In general, when a tone is just barely audible above its masked threshold, it is very difficult to detect changes in frequency or intensity, but if it is 10 db or more above this threshold, the discrimination performance will be nearly identical to the noise-free case. Since (a) the critical bandwidth increases above 1000 cps and (b) listeners report difficulty in listening to low frequency tones in noise, and (c) most environmental noises have most of their energy concentrated in the region below 500 cps, many systems have employed the 500-1000 cps range for tonal displays. It should also be noted that if the signal output of the display has a bandwidth less than the critical bandwidth and the noise output has a bandwidth greater than the signal bandwidth, improvements in noise reduction can be obtained by filtering before the display output.

Until now, we have neglected the fact that the human has two ears instead of one. It is well known that the second ear provides more than a duplicate channel of information. Specifically, the human's ability to localize sounds in space and, under certain conditions, his ability to detect signals in noise, depends on the use of the second ear. (It is interesting to note in this connection that many bats will refuse to fly if one ear is occluded.) In general, it has been found that in order to improve detection through binaural listening, the stimuli in the two ears must be different. Even more than this, the interaural differences for the signal component must differ from the interaural differences for the masking component. This would be the case, for example, when the sources of the signal and noise occur at different angles in space.

In order to obtain a feeling for the magnitude of the binaural effects which have been demonstrated in the laboratory, a number of examples will now be considered. If the target signal (i.e. the signal to be detected) is a tone 180° out of phase between the two ears, and the masking signal is continuous broadband noise that is identical in both ears, the binaural improvement will be about 15db at 200 cps and about 3db at 3000 cps. If the tone is presented to one ear only, but the noise remains the same in both ears, the binaural improvement will be about 8db at 200 cps and about 1db at 3000 cps. (In other words, presenting noise alone to the second ear makes it easier to hear the signal presented in the first ear.) If a 500 cps tone is presented

identically to both ears and the masking signals are uncorrelated noise, the binaural improvement will be about 5db. If the target signal consists of speech 180° out of phase between the two ears and the masking signals are identical noise signals, the binaural improvement will be about 5db. If the target signal consists of identical speech in both ears and the masking signal consists of uncorrelated voice babble, the binaural improvement will be about 12db for one babbler in each ear and about 5db for 7 babblers in each ear.

In general, the binaural improvements have been found to be greater at the lower frequencies and there appears to be a critical point in much of the data at about 1400 cps. This frequency, the period of which is approximately equal to the time it takes for sound to travel a distance equal to the width between the two ears, has also been found to be a critical frequency in many other types of data.

Two theoretical models which appear promising for explaining certain portions of the binaural data are the "time-gating model" and the "equalization and cancellation model".

In the time-gating model, oriented towards the masking of speech by speech (the "cocktail party problem"), the sum of the inputs from the two ears is gated in such a way that the desired talker's speech is left substantially intact while the speech from the background talkers (which does not overlap in time the speech from the desired talker) is suppressed. The knowledge of when to open and close the gate, i.e., when a given sound comes from the desired speaker, is obtained by cross-correlating the inputs from the two ears.

In the equalization and cancellation model, oriented towards continuous masking signals, the input from one ear is transformed with respect to the other until the masking components are substantially the same in both ears (the equalization process) and then the signals are subtracted from each other (the cancellation process). The degree to which the masking component is eliminated by this process will depend upon, among other things, the precision of the equalization operation. What happens to the target signal as a result of this process will depend upon how the interaural relations for the target signal compare to the interaural relations for the masking signal.

Although both of these models appear promising for explaining certain portions of the binaural data, neither of them appears to be adequate for explaining all the data. For example, the time-gating model is inadequate for explaining the results on tone signals masked by continuous noise. Similarly, the equalization and cancellation model does not appear to be capable of explaining the results for uncorrelated masking signals.

F. Summary and Comments

In summary, we have tried to make some general comments about the distinction between the problem of acquisition of information (pre-display problem) and the display problem, about various types of interference, about the presentation of auditory information, and about human auditory detection. Due to the space constraint on these papers and due to our lack of experience with the travel aid problem, these comments have, of necessity, been very incomplete.

In conclusion, we would like to say that, insofar as our limited experience in this area provides us with any insight into this problem, it appears to us that the three most basic problems which need to be considered in constructing a useful travel aid are (a) the problem of designing a sensing system with sufficient resolution to separate out the environmental elements of interest; (b) the problem of designing a display which will not overburden the listener; (c) the problem of devising system testing procedures which will take adequate account of the need for learning the display. Obviously, these problems are not independent of each other. For example, the more resolution one builds into the system, the harder it will be to find a display which does not overburden the listener. In our opinion, the difficulties encountered due to the existence of noise signals (both internal and external), although certainly constituting an important consideration in the overall system design, will not constitute a major limiting factor in the system's ultimate performance. Since that portion of the environment which will be of primary concern will be the environment relatively near by, it should be possible to design an active system such that the signal-to-internal-noise-ratio will, for most cases, be relatively large. Similarly, if the resolution problem can be solved sufficiently well to make the system perform adequately when no external noise sources are present, this resolution capability, combined with a wise choice of frequencies (i.e., frequencies where the external noise levels are relatively low), should suffice to make the external noise problem manageable.

Auditory Studies of Blind Travelers

Dr. John Curtis

Our work in audition has followed two paths: 1) an attempt to determine if there is a significant difference in auditory ability between blind and sighted subjects, and between expert and poor travelers; 2) an investigation of the important auditory cues useful for travel and how these might best be taught to the newly blind and to the poor traveler.

The first path has led to an analysis of primary auditory abilities and to a test of localization ability using traffic sounds.

The primary auditory abilities test was developed at the U. S. Naval Medical Research Laboratory by Dr. J. Donald Harris and is just now being used on a group of sailors to establish norms for that population. It consists of six tests. Three measure intensity discrimination for pure tones, one measures intensity discrimination for noise, and two measure pitch discrimination for pure tones.

To this battery of tests we hope to add some tests which measure binaural abilities. At the present we are considering a test of minimum interaural time and interaural intensity difference threshold for noises or pure tones. We are also trying to develop a test of signal selection ability, since it may well be that the expert traveler is better able to pick out important auditory cues from competing signals than is the poor traveler.

The second problem in determining auditory ability deals with a practical situation in locating the direction of a sound source. The assumption underlying this test is that the expert traveler is able to ascertain the direction of a moving sound source more consistently and accurately than the poor traveler. Further, the expert traveler may perform better than the sighted individual. To test this, a series of traffic sounds was recorded using an artificial head with a pair of microphones mounted at the ears. The head was positioned along the street in five different ways: facing the street, facing left, facing right and facing 45° to left and right. Fifty ten-second segments were then randomized using ten from each head position. The test was then presented binaurally and the subject asked to judge which way the head is facing. Using five sighted subjects and three blind subjects the results indicate that there is no significant difference in performance between the two groups. We are now in the process of expanding this investigation to include many more blind subjects, controlling the number of expert and inexpert travelers, since the blind subjects tested previously were all very good travelers.

It may be of interest here to mention that Dr. H. N. Wright used signal detection principles in the experimental design. The subjects in addition to responding with the direction of the head, were also asked to say "yes" if they were confident of their answer and "no" if they were not sure. From this it is possible to plot functions of criteria. The results indicate that the better traveler is more lax than is the poor traveler. Perhaps I should say here that my definition of expertness in traveling is based on a scale of mobility to be discussed later. The more mobile, the better the traveler.

Our second approach to auditory experimentation with the blind has consisted of developing a training tape - a prototype for future application in training the home-bound and the newly blind. The tape contains some of the important auditory cues which might be useful to the blind traveler. The above mentioned artificial head was used and both moving and stationary recordings were made along one block of a small town. The head was mounted on a go-cart to provide a stable and quiet carriage. Recordings were made at each of five points along the block. The points were selected so as to display the various changes in the aural environment. For example, at one point the buildings were right next to the sidewalk with plate glass windows, providing an excellent reflecting surface. At another point, the buildings were located about 20 feet from the sidewalk. The echoes from these two points are quite different.

The tape begins with a ten minute segment from the Ampex demonstration tape. This is a typical demonstration tape and consists of popular music and some sound effects. This is to familiarize the subject with headphone listening in general and binaural presentation in particular. A one-or two minute segment is then presented accompanied by narration. The first few segments simply point out specific sounds such as a car horn and pedestrians walking past. After each of the first three segments have been played they are presented again without narrative so that the subject may attend to the sounds. Then, some of the segments dealing with echoes are presented. These are accompanied by narration prior to the important auditory event. The last three segments on the tape consist of moving recordings with narration before and after the segment.

In an attempt to determine the usefulness of this training tape we divided 12 sighted individuals into three groups. The first group was taken to the recording area, also called the "mobility area", they were blindfolded and given a long cane. A little instruction in basic cane technique was given. Then, they were instructed to start at one end of the block and walk to the other end, and after a one or two minute pause, to return. After a fifteen or twenty minute pause, they repeated their round trip through the mobility area. The second group made one round trip, then listened to the training tape twice, and returned to the mobility area for another round trip. The third group listened to the training tape twice, then made two round trips.

Two methods of analysis were used. One was the time for travel. The second was an estimate of path. We first tried moving pictures of the subjects but this was not feasible because of other pedestrians blocking the camera. The method finally chosen consisted of selecting ten points along the course, selected so as to display the changes in the aural environment. The width of the sidewalk was marked off in six-inch intervals. As the subject walked down the street his lateral position on the sidewalk at each of these ten points was noted. The resultant series of scores yielded a rough estimate of the subject's path. An analysis of variance of both the time and path indicated that the within-group variance was the only significant variable. There were no systematic differences between groups.

We have changed our approach and are now using 25 blind subjects divided into two groups. One group will make five round trips. Several consultants who have visited the center agree that three trips are sufficient to stabilize the performance. The second group of subjects will first receive training and then make five round trips. This should eliminate a great deal of the variability. We are going to continue using both time of travel and path for analysis.

This winter, while snowed in, we are going to try loudspeaker presentation of the training tape since this would allow training of a large group. Possibly a tape of common sounds of the home and street might also be useful.

A TEST AND INTERVIEW BATTERY FOR BLIND TRAVELERS

David Winer

The objectives of the test and interview battery used in this investigation are to describe the sample of blind subjects tested as well as to relate mobility competency to I.Q. and emotional stability.

In order to adequately describe our subjects, a questionnaire was developed to serve as a personal history form for each subject. This questionnaire was divided into the following three categories: General Descriptive Data, Travel Training, and Mobility Competency.

The general descriptive data category contains questions that provide statistical information about the sample. They require no value judgments from either the examiner or the subject; and have to do with such items as name, date, place of birth, etc. Included in this category is a question asking the subject for the five most recent past addresses at which he has resided. This question was inserted to get an indication of the type of environment in which the subject may have previously traveled.

There are many other topics that would normally be included in a category such as this, for example: Marital Status, Employment, Recreation, and the like. They were not included in this questionnaire because of previous work done by Mary Bauman. In her study, Adjustment to Blindness, published by the Department of Welfare of the State of Pennsylvania in 1954, she correlated varying degrees of blindness with the information extracted from these topics. We didn't feel it necessary to reiterate her work.

The Travel Training category contains questions which are designed to furnish information about travel training programs, formal or informal, in which the subject has participated. Each subject is also asked if he thinks the program was helpful.

The purpose of the Mobility Competency category is to determine the subject's position on the fifteen-point mobility competency scale developed for this investigation.

It was felt necessary to develop a mobility scale in order that blind travelers could be systematically classified on an ordered scale. The scale should be based on what a blind individual does, not his intent, and should be applicable to all the blind.

In order for the above-mentioned requirements to be met, the mobility scale must be based on the following four assumptions:

(1) Traveling indicates a greater degree of mobility competency than not traveling.

(2) Traveling in unfamiliar environments indicates a greater degree of mobility competency than traveling in familiar environments.

(3) Travel competency can be ordered on a scale ranging from no dependency to complete dependency.

(4) A blind person will not travel with less assistance in an unfamiliar environment than in a familiar environment.

A discussion of each assumption follows:

(1) Traveling indicates a greater degree of mobility competency than not traveling.

We must first define what we mean by traveling: traveling means going from one place to another, usually with a purpose.

Now, what do we mean by not traveling? It can be said that individuals who restrict their traveling to their own home are not mobile and hence may be called homebound.

For the purpose of this scale, the place in which a subject lives has great bearing on whether or not he is a traveler.

The place in which a subject lives is defined by the area over which he has control. If he lives in his own home or has a private entrance in a multiple dwelling, he certainly has control over this area, that is, he usually knows where things are, etc. In order to be a traveler, the subject must go beyond his yard. On the other hand, if an individual lives in an apartment house or does not have a private entrance, the subject is considered a traveler if he even leaves his specific living quarters. So we can see that the place in which the person resides can have some effect on his mobility competency.

(2) Traveling in unfamiliar environments indicates a greater degree of mobility competency than traveling in familiar environments.

An unfamiliar environment is one in which the subject has never traveled. A familiar environment is one in which the subject has previously traveled. Also, as stated before, if the subject's travel was restricted to his home and yard, he was classified as a non-traveler or homebound.

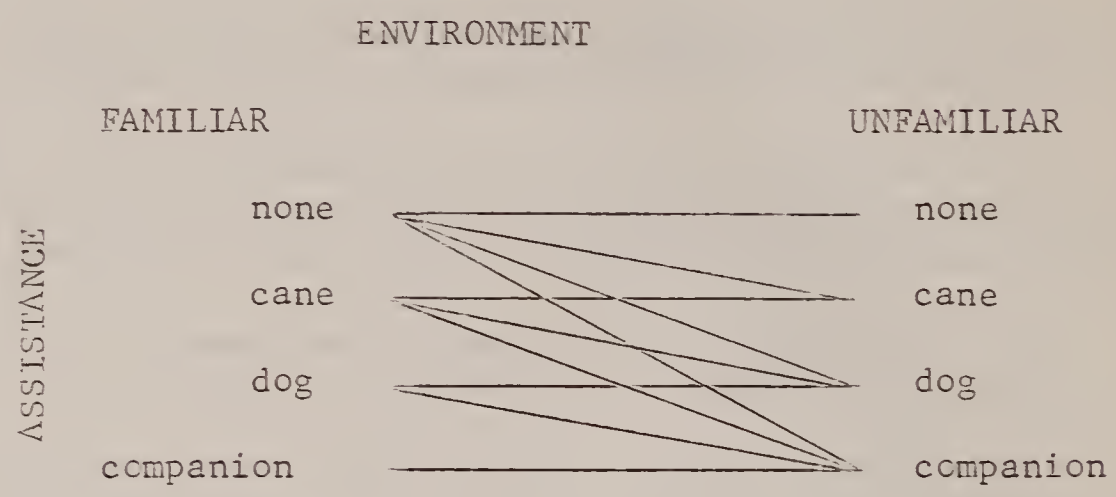
(3) Travel competency can be ordered on a scale ranging from no dependency to complete dependency. Here we see just what types of assistance an individual may require when traveling. The completely independent person will require no assistance. The completely dependent person will require assistance in the form of a companion. Between these two points on the dependency scale we see the other two most common types of assistance; the cane, and the guide dog, the cane indicating less dependency than the guide dog. Thus, we can designate the four points on this scale as none, cane, dog, companion.

(4) A blind person will not travel with less assistance in an unfamiliar environment than in a familiar environment.

We can now relate the four (4) kinds of assistance mentioned above to each kind of environment.

Figure 1.

The relation between amount of assistance and kind of environment under Assumption 4.



The above figure accounts for ten positions on the scale. However, we must also include the following five:

1. uses no assistance in a familiar environment; does not travel in an unfamiliar environment.

2. uses a cane in a familiar environment; does not travel in an unfamiliar environment.

3. uses a dog in a familiar environment; does not travel in an unfamiliar environment.

4. uses a companion in a familiar environment; does not travel in an unfamiliar environment.

5. does not travel in either environment.

When we do this, we find that we have fifteen (15) combinations that make up our mobility scale. Successive degrees of mobility on this scale are ordered from the greatest degree to the least degree of mobility competency. The highest degree of mobility competency, that is, position No. 1, will be occupied by an individual who travels in both familiar and unfamiliar environments with no assistance. The lowest degree of mobility competency, that is, position No. 15, will be occupied by an individual who does not travel in either environment.

After developing this scale, we wanted to determine if it was a valid indication of degree of mobility competency. The description of each scale position was paired twice with all others, the second time opposite in order to the first. Such pairing of the fifteen (15) scale positions yielded two hundred ten (210) pairs. These pairs were presented singly to five (5) judges in a different random order to each. The judges were asked which of the two (2) scale descriptions they received represented, in their opinion, the greatest degree of mobility competency. The results from these comparisons were then correlated with the mobility scale from which the original pairs were drawn.

High and significant correlations (used a rank-order correlation) (significant at 1% level-ranged from +.762 = +.999) between the judges' ratings and the logically derived scale indicated that the mobility scale as defined previously is valid.

Let us now discuss the test battery that was used in the investigation. Each subject was given the Verbal Scale of the Wechsler Adult Intelligence Scale (WAIS 1955) and the Emotional Factors Inventory (EFI).

In reference to the WAIS:

The verbal scale portion of WAIS was chosen to be administered to each of our subjects. The performancee scale was not applicable to this investigation because sight is required for this portion of the test. Consequently, giving the performance scale would violate the conditions under which the WAIS was standardized.

The purpose of giving the WAIS is to determine each subject's verbal I.Q. and then relate it to mobility competency as defined by our mobility scale. The hypothesis is that mobility competency and I.Q. are positively correlated.

The complete verbal scale was given to each subject. The scale is composed of the following six (6) tests: (1) Information, (2) Comprehension, (3) Arithmetic, (4) Similarities, (5) Digit Span, and (6) Vocabulary.

Although the majority of published literature to date in the area of testing blind adults have utilized the Wechsler-Bellevue Form I or Form II, we investigated the possibility of using the WAIS: We found that in a study by Cole and Weleba in 1956, forty-six (46) subjects were given both the W-B I and the WAIS alternately and successively and the correlation between the W-B I verbal scale and the WAIS verbal scale was .87.

Standardization of the two (2) scales was also investigated. It was found that the WAIS standardization sample was national and included Negroes proportionate to the 1950 census. The W-B I was standardized largely on white persons in New York State. Wechsler also states in his text on the WAIS that the new scale has the advantages of less ambiguity and more adequate restriction of item difficulty than the W-B I. We concluded from the above that we were warranted in using the WAIS to test our subjects.

In reference to the EFI:

The EFI is a personality inventory developed by Mary Bauman at the Personnel Research Center in Philadelphia. This scale includes material indicative of personality charactersitics, as well as material indicative of problems arising from blindness

The purpose of using this test is to obtain an estimate of each subject's emotional stability so that it can be correlated with his mobility competency. The hypothesis is that emotional stability, as indicated by the EFI, is highly correlated with mobility competency.

The questionnaire-type personality inventory consists of one hundred seventy (170) statements which are administered to the subject either by tape recording or directly by the examiner. In this investigation the statements were read directly to the subject. The subject is asked to indicate whether he agrees or disagrees with each statement. For example, the statement may be: "I am easily discouraged." The subject must say whether this item is true for him or not.

This inventory was originally standardized on two hundred (200) persons of both sexes. The degree of visual loss of this standardization group runs from legal blindness (20/200) to total blindness. New norms are now available for this inventory. They are based on the responses of twenty two hundred (2200) blind individuals.

The EFI is composed of the following eight (8) diagnostic categories: (1) Sensitivity, (2) Somatic Symptoms, (3) Social Competency and Interest in Social Contacts, (4) Attitudes Toward Blindness, (5) Feelings of Inadequacy, (6) Depression, (7) Paranoid Tendencies, and (8) Validity.

A short description of each category follows:

1. Sensitivity:

The statements in this category were designed to indicate general neurotic tendencies, such as, a tendency to worry, to cry easily, and general emotional instability. Examples of some of the items are: "Many times I feel afraid of something I know cannot hurt me"; "I get spells of the 'blues'"; and "I find changes in my routine very disturbing."

2. Somatic Symptoms:

This category consists of statements that concern health difficulties usually associated with nervous tension. Examples of some of the items are: "I cannot work in a job where there is dust"; "I am often bothered by an upset stomach"; and, "My heart often pounds so that it bothers me."

3. Social Competency:

The statements in this category attempt to determine an individual's attitude in social situations. It also seeks to find out the person's willingness to seek social contacts. Examples of some of the items are: "I go to dances and other social affairs whenever I have the chance"; "I usually have a good time at parties"; and, "I usually stay in the background at parties or social occasions."

4. Paranoid tendencies:

The statements in this category were designed to uncover attitudes of distrust and suspicion as well as the notion of being persecuted. Examples of some of the items are: "Other people continually steal my ideas and take credit for them"; "You have to watch most people or they will cheat you"; and, "People are always just watching their chance to get something on me."

5. Feelings of Inadequacy:

This category attempted to discover feelings of inferiority and of the inability to meet competition. Examples of some of the items are: "It is fun to make things sound bigger than they are"; "It takes pull to get much of anything in this world"; and, "People expect so much of me that I am forced to make a good many excuses."

6. Depression:

This scale is a measure of morale and hopefulness. Examples of some of the items are: "I often feel I would be better off dead"; "Life is just one disappointment after another"; and, "I feel that blindness is the worst affliction that anyone can have."

7. Attitudes Toward Blindness:

This group of statements was designed to disclose the subject's feelings about blindness in general, about himself as a blind person, and how society should react to him as a blind individual. Examples of some of the items are: "People should give me special consideration because of my handicap"; " A blind person should not be criticized for what he does or says"; and, "Almost all blind people have many unusual abilities."

8. Validation:

Validity items were included to measure an individual's understanding of the inventory content and his frankness in responding to it.

RESULTS:

To date, only four (4) totally blind subjects have been tested. As a result it is felt that the N is too small to test the two (2) hypotheses stated above, by any correlational methods.

However, it is found that the individual with the lowest I.Q. in the group also shows the highest degree of dependency and the lowest mean standard score on the EFI. The other three (3) subjects do not fall into such a neat pattern. The range in I.Q. for these three (3) is 25 pts, but they all score within .4 of a standard score of one another on the EFI. The mobility competency also differs within the rest of this group, but it shows no direct relation to either I.Q. or emotional stability.

Breaking the data down on the EFI to the raw scores on each subtest for each subject we find that three (3) of the subjects have scores on at least six (6) out of the eight (8) tests that fall outside of the ± 1 standard deviation for each test. All of the nineteen (19) test scores beyond ± 1 S.D. fall on the lower end of the scale, indicating that the subjects are much more emotionally stable than the average of the standardization sample. The fourth subject also scores lower than the average, that is, better adjusted, but is still within ± 1 S.D. most of the time. All of the four (4) subjects also have higher than average I.Q's as measured by the WAIS. However, before we can draw any specific conclusions, our N will have to be increased substantially.

CONTINUATION:

With the help of Mr. Dupress at the American Foundation for the Blind, we are in the process of scheduling approximately twenty-five (25) more totally blind subjects. To each subject will be administered the History Form, WAIS, and EFI.

DATA SHEET

	SUBJECT	VERBAL I.Q.	MOBILITY COMPETENCY	MEAN STANDARD SCORE ON EFI
I	B.H. (f)	122	5	6.4
II	J.B. (m)	114	5	6.1
III	G.T. (f)	139	10	6.0
IV	A.G. (m)	103	10	5.5

INDIVIDUAL EFI SCORES

I

Test No.	Raw Scores	St. Scores
1	1	7.0
2	1	6.3
3	4	6.3
4	0	6.7
5	0	7.0
6	0	6.3
7	1	7.0
8	6	4.5

II

Test No.	Raw Scores	St. Scores
1	4	5.8
2	6	4.5
3	3	6.7
4	3	5.5
5	0	7.0
6	0	6.3
7	2	6.7
8	2	6.3

III

Test No.	Raw Scores	St. Scores
1	2	6.7
2	3	5.3
3	4	6.3
4	1	6.3
5	1	6.3
6	0	6.3
7	2	6.7
8	6	4.5

Test No.	Raw Scores	St. Scores
1	6	5.5
2	10	5.0
3	12	4.8
4	2	5.8
5	2	6.3
6	1	5.8
7	7	5.5
8	4	5.5

HISTORY FORM

1. Name (Last, First, Middle)

2. Examiner | 3. Date

4. Referred by | 5. Sex

6. Maiden Name if Married

7. Date of Birth | 8. Place of Birth (City, State)

9. Present Address (Street, City, State) | 10. Phone No.

11. Past Addresses (Street, City, State)

1. _____
2. _____
3. _____
4. _____
5. _____

12a. Were you ever in the Armed Forces

12b. Branch of Service

Army_____ Navy_____ Air Force_____ Marines_____Coast Guard_____ Other____

13. Rank_____ Serial No._____ VA Claim No._____

14.

EDUCATION	B/S	NAME	GRADE COMPLETED	LOCATION
Grammar				
High School				
College				
Technical Training				

Comments:

TRAVEL TRAINING

15a Did you ever have any travel training

15b. What types of training did you have

15c. Do you feel that the training has helped you

Comments

16. BLINDNESS

a. Age at which totally blind

b. Cause of blindness

c. Sudden Gradual

d. Treatment

e. Examining Physician Location

Comments

17. Determination of Mobility Competency

A. Assistance

1. Do you ever go away from the place in which you live

2. If yes, do you ever go alone or do you always go with somebody else

3. When you go alone do you use anything to help you such as a cane, dog, etc.

4. If (1) is yes, during the last year did you go anywhere that you have never been before

5. If (4) is yes, did you go alone or with somebody else

6. When you went alone, did you use anything to help you such as a cane, dog, etc.

17. (Cont'd)

B. Subject's Position on Mobility Scale

	Familiar	Unfamiliar
none	_____	_____
cane	_____	_____
dog	_____	_____
companion	_____	_____

C. Numerical Position on Mobility Scale _____

Comments

18.

I. Q.

19 EFI SCORES

1. Sensitivity _____
2. Somatic Symptoms _____
3. Social Competency _____
4. Paranoid Tendencies _____
5. Inadequacy _____
6. Depression _____
7. Attitudes Toward Blindness _____
8. Validation _____

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PUBLIC ATTITUDES TOWARD BLINDNESS *

Dr. Martin Whiteman
Dr. Irving F. Lukoff

If we were to look at the natural history of an attitude, any attitude, and if we were to look long enough, we might observe some common phases and sequences. The attitude develops within a certain kind of individual who is exposed to certain experiences. As it develops, the attitude may take on a structure, for the beliefs and evaluations embodied in the attitude become organized in certain ways. Also the attitude need not be temporally static. There are certain events that produce attitudinal shifts and changes in time. And finally the attitude itself may occasion new behaviors and new orientations both within the individuals having the attitude and within the individuals toward whom the attitude is manifested.

If we study attitudes, it may become useful to break into such sequences of events, isolate them as it were, and reduce them to "problems." With further study, the problems become reduced to variables and to relationships among variables. If we become really empirical, the variables become defined by, or at least coordinated to observable test procedures. The products of the latter are eventually analyzed statistically to yield information about the natural history of attitudes.

Let us look at some of these problems with reference to attitudes toward blindness. Four problems suggest themselves.

First there is the problem of attitude structure. How are these attitudes to be described or defined? Is there, for example, a unitary tendency toward or away from blind people or is there rather a set of such tendencies such that an individual may be favorable with respect to one attitudinal component, unfavorable with respect to a second, and neutral with respect to a third.

Second there is the question of attitude development. What determining conditions foster or retard the growth of these attitudes? Do the individual's demographic, social, and personality characteristics make a difference in the intensity with which attitudes toward blindness are held?

Third, there is the question of attitude change. What sort of experiences, what kind of information or knowledge about blindness is conducive to attitudinal shifts and what kinds of individuals are most and least susceptible to the impact of such events?

Fourth, and finally, the question of attitude function is important. What effects do these attitudes have upon the adjustment of the blind person himself? Do they affect his self-concept, his own attitude toward sighted people, and the degree to which he attains some measure of personal independence in his economic or daily activities?

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In an attempt to answer some of these questions, we have studied a number of sighted groups. These include graduate social work students, a college group, a large sample of high school students, a community center group, and individuals of a wider range from middle and low income housing projects. We have also analyzed data gleaned from a random sample of 500 blind individuals, so that the total studied with reference to the above problems numbers around 3,800.

Our research design has incorporated both experimental and survey procedures -- survey with respect to the assessment of attitudinal components and experimental with respect to the assessment of attitudinal change in these components.

With regard to the question of attitude structure, we have found that there is a good deal of independence among certain attitudinal components. To take an example, there is a difference between the evaluation of blindness and the evaluation of blind people. Social work students, for example, may rate blindness as more severe than physical handicap, but will not rate blind people more severely maladjusted than physically handicapped people. The image of blindness held by many people is more severe than the image they have of blind people, probably because blindness has more personalized connotations. Take these figures derived from a study of 2,400 high school students. Twenty-four percent agree that "Blind persons tend to be more unhappy than other physically handicapped persons." However 55% agree that "Of all physical handicaps, blindness would make me most unhappy." Now if blindness becomes personalized, it seems to become even more devastating for 71% agree that "I imagine that suddenly becoming blind would be more frightening than becoming suddenly handicapped in any other way." Note how the percentages shift from 24% to 71% depending upon whether the referent is blind people or blindness, or personalized blindness.

The component approach throws some light on the conditions under which one obtains individual consistency with respect to relationships between attitudes toward blindness and toward physical handicap. If we were to ask the question of whether one's attitude toward blindness is predictable from his attitude toward physical handicap, the answer is, "It depends." If the prediction is from one attitudinal component regarding physical handicap to the same attitudinal component regarding blindness, the relationship is fair. However, if one attempts to predict from an attitudinal component regarding physical handicap to a different attitudinal component dealing with blindness, prediction falters. Let us make this more concrete.

Take two analogous items dealing with a particular component, say the evaluation of disability. Suppose one item deals with physical handicap, for example "Physical handicap cuts people off from most worthwhile experiences," and its analogous item deals with blindness, "Blindness cuts people off from most worthwhile experiences." Take another two analogous items dealing with a second component. Suppose these two focus on the perceived characteristics of disabled people rather than upon the disability per se, for example, "Some say it is natural for physically handicapped persons (or blind persons) to feel sorry for themselves. Of physically handicapped persons (or blind persons), I would imagine this is true for (select one) - all or practically all, many, a moderate amount, few, or none or practically none." The relationship between components, even though within a given disability, is poor. Thus the correlation between items dealing with the evaluation of physical handicap and the evaluation of physically handicapped people is only .13 while the two items referring to blindness and blind people correlate .22. However the relationship within components is appreciably better even though the responses are to different disabilities. Thus the two items referring to blindness and physical handicap and their effect on most worthwhile experiences correlate .53 while the two items referring to the sorrowful characteristics of blind and of physically handicapped people correlate .61. Similar considerations obtain when the components deal with pity towards blind people, or with readiness for interaction with them.

Still another aspect of the component approach involves the relationship between the perceived attributes of blind people and the readiness for interaction with blind people. In our college samples for example, we find that seeing blind people as personally unhappy is conducive to an expressed unwillingness for personal interaction with blind people, but not to an expressed disinclination for blind people's participation in integrated community settings. This finding suggests distinctions between readiness for personal contact with blind people and readiness for the more impersonal association with them. In our high school population a social distance scale throws some light on this point. Thus the idea of having a blind person as a fellow club member finds 8% of the group responding "probably wouldn't like it" or "wouldn't like it at all" but when the idea of dating a blind person is presented, 62% don't care for the idea.

The component approach is also helpful in clarifying questions of attitudinal development, since it raises the question of whether two attitudinal components may have different etiologies. In our study of 109 residents of middle and low income housing projects, an analysis of items dealing with attitudes toward blindness revealed four clusters. The first, called Evaluation of Blindness, dealt with tendencies to see blindness as uniquely frustrating among physical handicaps and included such items at "Blindness cuts people off from most worthwhile experiences," or "I feel more sympathy for persons who are blind than for any other physical handicap." A second cluster, called Emotional Traits, differentiated individuals according to the degree to which they perceived blind people as unhappy or maladjusted. Items dealt with the degree to which blind people are perceived to feel sorry for themselves, to feel touchy

about their blindness, or to have unique emotional experiences. A third cluster, called Positive Stereotype, focussed on the degree to which blind people were viewed as possessing special abilities or gifts. Thus individuals scoring high on Positive Stereotype tend to believe that the blind have unusual musical gifts, or that "You can't keep anything secret from a blind person in the same room," or that "Blind people can get around without help because they are gifted with unusual abilities."

A final cluster, Protective Interaction, dealt with tendencies toward adopting a protectively segregated pattern of community activities for blind people, for example the espousal of sheltered workshops or of segregated community programs as solutions for employment or leisure-time problems of blind people.

What is interesting is the differential pattern of relationships exhibited by these four scales to more general personality and attitudinal scales. For example, there are three independent personality measures which are related to a severely unfavorable evaluation of blindness. People who perceive ambiguous and schematically drawn faces as angry rather than friendly tend to have an unfavorable evaluation of blindness. Also people who describe themselves as taking relatively little pleasure in close contact with others, i.e. in doing small favors for others, in relating things to others, in receiving encouragement from others - these too are people whose evaluations of blindness are significantly negative. Finally those respondents who tend to take a punitively authoritarian orientation toward others manifest a relatively harsh evaluation of blindness as well. Thus we see that those who see the world as unfriendly, or those who describe themselves as distant from others, or those who identify strongly with power may also express these orientations in negative evaluations of blindness.

With reference to the positive stereotype, however, the pattern of personality determinants shifts. Here the three independent personality or attitudinal variables showing the highest relationships with the positive stereotype are (1) the tendency to see people as unfriendly, (2) relatively low intelligence and (3) an attitude of extreme religious fundamentalism. Thus the sighted individual who sees the blind person as a "blind genius," to use Harms' term, is prone to see the world as a threatening place and perhaps for this group, the positive stereotype represents a reading of compensatory functions into blind people. Or the positive sterotype may be subscribed to by people with relatively little critical acumen as assessed by the intelligence score, or by people with absolutistic beliefs in a highly personalized deity. It is quite possible that the latter two variables are tapping a kind of naivete dimension since both intelligence and religious fundamentalism are significantly correlated with education and social class.

When we deal, however, with a third component of attitudes toward blindness, the tendency to see blind people as personally unhappy, neither intelligence nor fundamentalism nor the negative projective tendencies show significant relationship. What does relate to the perception of blind people as emotionally maladjusted is the sighted individual's own expressed level of anxiety. It is the more anxious individuals, as assessed by self-descriptive items, who tend to perceive blind people as unhappy and upset.

Finally, the two attitudinal components, Protective Interaction and Emotional Traits are differentially related to two facets of experience with blindness -- contact or acquaintance with blind people and information about blindness. Those who are acquainted with blind people are significantly less prone to see them as emotionally distraught. Here lack of contact seems to help build up a negative stereotype. However contact is not significantly related to readiness for more community integration of the blind. The situation is quite the reverse in the case of information about blindness. The more informed sighted individuals are more prone to accept community integration, but information is essentially unrelated to the emotional stereotype. It is interesting to speculate that if the Interaction and Emotional Traits indices were combined together in one scale, these relationships with experiential variables would cancel each other out. The relationship between information about blindness and the readiness for community integration does not of course necessarily imply that increased information produces a more receptive interactional orientation. It may be that those with more favorable attitudes toward blindness are predisposed to assimilate and retain information about blindness or that both attitude toward blindness and information about blindness are mediated by some third factor or factors. The evidence points to the latter case. Educational level for example, correlates significantly both with degree of information about blindness and with espousal of community integration. Control on educational level results in a non-significant association between information about blindness and interaction level, indicating that the apparent causal efficacy of information, in this case, is spurious.

We turn now to the question of attitude change. Here the component approach affords some guide lines as to the kinds of communications that may prove effective attitude changers. The reasoning is that if such components as Evaluation of Blindness, Positive Stereotype, Emotional Traits, Interaction, and Pity-Sympathy are relatively independent of one another, each should be selectively responsive to specific communications. Thus a communication aimed at changing an individual's evaluation of blindness may indeed be effective along this dimension, but may prove quite ineffective in producing change along the remaining dimensions, e.g. in effecting alteration in the perception of blind people's emotional makeup, or in alleviating the positive stereotype. A set of five written communications were therefore designed. The content of each was aimed at changing one of the five different attitudinal components mentioned above. At the same time every attempt was made to hold constant such factors as length of communication, the level of language used, and the order in which some common structural features of the communications were introduced.

These communications were randomized among several thousand high school students who also received attitude toward blindness questionnaires before and after the communication experience. A control group received the questionnaire without receiving any communication. An intensive analysis of the pre- and post-attitudinal indices is now underway and will be completed shortly. However, our preliminary analyses of the scores of the various communication groups on scales designed to tap the five attitudinal components reveals some significant differences in line with the specificity hypothesis. Thus the group receiving the communication aimed against excessive or indiscriminate pity for blind people scored in the predicted direction on the pity-sympathy scale. However there were no differences between this group and the others on scales dealing with interaction, or with the personal evaluation of blindness. Similar findings obtain in the case of the positive stereotype communications whose effects are significant, and in the predicted direction but specific to the component at which it is aimed. However, the interaction, the personal evaluation, and emotional traits communication were ineffective across all components.

Our final problem deals with the question of attitude function, or the effects of these attitudes upon blind people themselves. If these attitudes are significant, they become so because they are internalized by the blind person and in some sense affect his adjustment. This phrase "in some sense" needs clarification. There are three areas on which these internalized attitudes may reverberate. The first is the individual's self-concept, his general feeling about his own value. One would expect that negative attitudes toward blindness on the part of a blind person would be related to general feelings of self-negation. A second area is the blind individual's reaction, or counter-attitude toward sighted people. One would expect that those blind persons who do not themselves identify with the public's dreary appraisal of blindness may exhibit more of a critical attitude toward such a public than do blind individuals who do introject such public attitudes. A third and final area deals with the blind person's behavioral independence with respect to employment, to activities such as eating and shopping, and to travel.

From the data gathered in the study of 500 blind individuals in New York State, a number of indices relevant to the above areas have been constructed. Thus an Evaluation of Blindness index has been constructed from response to items dealing with the degree to which the blind respondent sees blindness as intrinsically frustrating in such areas as travel, earning a livelihood, and maintaining an adequate social life. A Self-evaluation index was constructed from items tapping the degree to which the respondent rates himself highly on such socially valued traits as friendliness, courage, self-confidence, and self-control. An index of Critical Attitudes was constructed to assess the degree to which the respondent is critical of sighted people's orientations and behaviors toward the blind. Finally a Role Index was constructed to differentiate the respondents according to the independence

of their adjustment in various life areas, e.g. employment, travel, personal skills.

The relationships exhibited between the blind respondent's evaluation of blindness and phases of his adjustment, as assessed by the Self-evaluation index, by the Index of Critical Attitudes, and by the Role Index do conform to theoretical expectations. Thus the blind respondent with an unfavorable evaluation of blindness has a generally low self-concept, displays relatively little critical attitude toward the sighted, and tends to adopt a more dependent mode of adjustment. We are planning further analyses in this area to control for extraneous variables and to test the cogency of this explanatory schema.

By way of summary - This paper has been concerned with a number of problems related to public attitudes toward blindness. A major emphasis has been upon attitudinal components -- upon their description, their mediation by different personal values, and their differential sensitivity to methods of attitude change. A second emphasis has been upon tracing through the workings of such introjected attitudes upon the self-concept of the blind person, upon his own attitudes toward the sighted, and upon the degree to which he has obtained independence in his mode of travel, in his work, and in daily activities.

PRIMARY GROUP ATTITUDES AND THE ADJUSTMENT OF BLIND PERSONS*

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Introduction

Social scientists and psychologists who have studied the problems of adjustment of blind persons are almost unanimous in noting that the observed patterns cannot be explained merely by the presence of a visual deficit. Some kinds of activities cannot be performed by blind persons, or are difficult and require a great deal of help. Other experiences may be unavailable to the blind; or they must be perceived by substituting alternate sensory mechanisms that remain to them. However, after acknowledging this, it is apparent the limitations imposed by blindness are more profound and extensive than can be attributed to deficient vision alone.The problem, then, is to identify the elements that characterize this response to blindness. This paper will examine a series of hypotheses regarding adjustment in order to ferret out the contribution of attitudes of persons with whom the blind person engaged in primary social relationships, and attempt to trace the concomitant variations in adjustment.

The emphasis here is on the adjustment of blind persons; consequently, behavioral areas have been selected that appear useful to describe blindness. The thesis that pervades this analysis, however, is that blindness is not fundamentally unique.[1] Blind persons can be understood by working with precisely the same principles that are relevant for understanding the adjustment of any group that occupies a special position.

The Source of Data

The information used in this analysis is derived from a sample survey of 500 legally blind persons in New York State.[2] The sample was limited to persons between 15 and 54 for two reasons: (1) to avoid an excessively aged sample, and (2) to provide a sample that deals with the problems of persons in the active years of life when the rehabilitation goals are more or less similar. With the cooperation of the New York State Commission for the Blind, it was possible to select a sample that is representative of the blind population in the entire state. With compulsory registration in force for 15 years at the time of this survey, the vast majority of blind persons were in this register: only a negligible number of persons refused cooperation (22 or 4% of the sample). In the five counties that make up New York City, a random sample was selected for interviews. The eight counties outside New York City were selected to reproduce the overall state characteristics on basic economic and social characteristics. In addition, the completed sample, when contrasted with the total register, showed a close correspondence in sex, age and duration of blindness, so that the sample can be assumed representative of New York State legally blind persons. The group who were above 10/200 were deliberately under-sampled by one-half, in order to provide a sufficient number of cases at the more limited end of the visual scale.

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The interviews were conducted by graduate social workers, recruited in New York City, Syracuse and Rochester. They were trained specifically for the purpose of the research interview. The instrument contained a variety of structured items, open-ended questions and rating scales designed to obtain various background information, personality traits, performance in designated social areas, and selected attitudes and values.

The nature of the sample is such that it includes, in addition to those who frequent agencies serving blind persons, the relatively large numbers with little or no contact with agencies for blind persons. From the analysis of the data, had we obtained the sample in the usual way--from agency caseloads--we would have missed many independently oriented blind persons, as well as a large number of the most poorly adjusted, who seem to have been missed by the agency network.

Significance of Attitudes for Adjustment

Attitudes toward blindness and blind persons have been credited with a central role in the response a blind person makes toward his handicap. [3] If one central theme can be discerned in the literature by and about blind persons it is this: sighted persons have an assortment of peculiar notions about blindness, with a heavy encrustation of pity organizing these themes that, in turn, color the interaction between the blind and sighted. This thesis then maintains that the effect is reflected in the response a blind person makes to his handicap. He may come to accept the notions the sighted majority holds, and take on these behavior patterns as a reflection of these widely prevalent notions; or he may vigorously reject these presumptive attitudes and aggressively pursue a different course of action. [4] Various traits, such as age of onset of blindness, or personality factors, are presumed to intervene between attitudes and the response to blindness, perhaps explaining the divergent responses to the attitude network that surrounds blind persons.

The nature of these attitudes, their sources in the experience of sighted persons and in their personality make-up is a focus of a number of investigations. [5] However, despite the importance of this focus on attitudes toward blindness, little direct evidence has been accumulated concerning the effectiveness of these attitudes on the behavior of blind persons. Even if there is a good deal of uniformity about attitudes toward blind persons, their impact on blind persons behavior cannot be directly deduced from this fact alone. In fact, there is a good deal of variability in the attitudes people have about blindness; [6] and, in turn, there is a great deal of variability in the behavior that can be observed by blind persons in all areas of adjustment. Therefore, it is necessary to look at attitudes toward blind persons and blindness as an independent variable influencing the behavior of blind persons, and not merely view attitudes as a dependent variable. In this paper some evidence will be assembled concerning the variations in responses made by blind persons as a consequence of the attitudes they encounter in the sighted persons with whom they interact.

The problem that is at the core of the analysis is this: despite the assumption that there are widely current stereotypes held by most persons about blindness, the blind themselves do not invariably share these assumptions; on the contrary, an active (and vocal) group of blind persons have established patterns of adjustment that are clearly at variance with the widely held notions about the limitations of blindness, and the presumed personality correlates that adhere to the blind. Instead of a passive, dependent personality, with its air of cheerful resignation, many blind attempt to conform to sets of values that stress independence, achievement, and manipulation of the environment. Other blind, however, become caught up in the socially structured patterns of values and organizational arrangements, and, outwardly at least, seem to conform to the traditional conception of blindness. The question, then, that raises many fundamental theoretical issues and organizes the analysis proposed here is: how do persons placed in similar situations with presumably similar social definitions of their potential and behavior, develop such markedly different values, behavior patterns and goals?

The Analysis

The major hypothesis that guides this analysis attempts to wrest some uniformity from the multiple factors ordinarily associated with adjustment. Obviously, an assortment of factors are associated with adjustment: residual vision, intelligence, social class origins, ethnicity, age, personality traits, etc. But this implication of multiple influences, though apparent from other investigations, [7] and from the findings to be presented shortly, fails to grapple with a number of problems of theoretical and practical significance. First, some way must be found that can organize these findings into a more compact series of generalizations, if it is at all possible. Second, most of the influences on adjustment are simply incapable of alteration or change, if their role is basic, for effective rehabilitation efforts. Neither intelligence, social class origins, or, for the most part, the provision for some residual vision, can be tinkered with by vocational counsellors or social workers who counsel the blind.

Not only are these factors irreversible, they fail to grapple with the complexities of adjustment that face blind persons on a day to-day basis. Yet, in everyone's experiences there are handicapped persons who seem to circumvent the influences cited above. There are totally blind persons who are well adjusted, as well as partially seeing legally blind persons who are poorly adjusted. Among the well adjusted are found Negroes, older blind persons, still others with very modest intelligence and educational achievement who seem to defy the general patterns. These can be viewed as sports, or dismissed as instances reflective of poor measurement techniques, and therefore not <u>really</u> well adjusted; or, other factors, not included in the analysis may be invented to explain away the discrepancies.

On the other hand, there are persons who appear to present a promising profile for positive adjustment but who are poorly adjusted. Poor motivation can be inferred to provide an explanation for an observed lack of adjustment; but this may not direct proper attention to the source of this lack of motivation, and consequent efforts at rehabilitation may prove fruitless.

The viewpoint presented here is that <u>various predictors or factors associated with adjustment do so because they are proximate indicators of the environmental press that surrounds the blind person</u>. To illustrate: a partially seeing person may not have to face up to the protectiveness and solicitousness that a totally blind person is likely to encounter in his interaction with family and friends; a person whose social origins are middle class may find, generally, less paternalism and stronger expectations that he be independent, than, for example, some one of whose origins are lower class. Similar considerations apply to each of the factors ordinarily associated with adjustment. Insofar as they predict different outcomes, they do so because of an "intervening" set of conditions: The attitude milieu that surrounds the blind person. Between social class, or age of onset, or residual vision, or the other factors that are associated with blindness, it should be possible, according to this hypothesis, to identify an attitude network that helps to explain the association between these factors and adjustment. If this hypothesis is satisfactory it will enable us to predict not only those instances where these "predictors" are correlated with adjustment; it will also enable us to explain those instances that depart from the usual predictions, whether it is the blind person with 20/200 visual acuity who is poorly adjusted, or the person with a college education, who doesn't appear able to perform as well as most of his peers.

Some Problems of Measurement

To present this analysis we have to discuss three classes of information. First, it is necessary to know how adjustment [8] is being measured; second, how the attitude network surrounding the blind person is indexed; and, third, what classes of predictors associated with blindness are used to test the hypothesis.[9]

<u>Adjustment</u>: Adjustment is a complex concept that shares almost as many meanings as there are persons attempting to cope with adjustment. Although various subjective elements can enter into the concept, such as feelings of personal satisfaction and well-being, the index proposed here focuses, instead, on the behavior of blind persons. This focus is justified on several grounds. First, where relevant, it can be related to personal evaluations of well-being or psychological health. Secondly, the focus of rehabilitation centers and others concerned with adjustment is on the performance of blind persons as workers and as normal members of families and neighborhoods. In addition, by dealing with actual performance, the difficult problems associated with a more psychologically based concept are circumvented. Problems of reliability and meaning are less likely to be questioned. And it is, in a fundamental sense, the outcome sought in all rehabilitation efforts, and the "pay-off" even for "psychological" concepts of adjustment.

The typology of adjustment is derived from four behavioral samples: employment; travel independence; independence in eating and independence in shopping. These four components were selected since they involve behavior in significant contexts, and characterize the individual in even more extensive ranges of behavior. These four components are not independent of each other; nor is this necessary for the uses to be made of this typology. Each of these components was selected on the assumption they reflect, in some measure, a variation in behavior along a dimension of independence-dependence. If this is true, then we would expect them to be associated with each other. They also involve the person in a fairly wide range of significant activities which can then be reasonably assumed to characterize the persons under study.

The special situation blind persons find themselves in was considered in selecting these particular behaviors. Employment is a perennial problem for the blind. Despite rehabilitation programs, and the demonstrated talents of numbers of blind persons in many types of marketable skills, the general assumption of incompetence in most activities by employers (and others), makes it very difficult for the blind to obtain employment. Many have to fall back on sheltered workshops, or on various forms of aid to the blind.

The solicitousness of sighted persons toward the blind, perhaps motivated by their incomprehension of the ways in which the remaining senses can provide abundant cues for carrying on most activities, encourages the sighted to perform all kinds of chores for the blind they can adequately perform for themselves. Thus, blind persons vary in the extent they travel independently and extensively. With the exception of a few who have additional handicaps, there is no intrinsic reason for blind persons to be dependent on other persons to lead them about, although there may be strong pressures against independent travel with concomitant fears and poor motivation for travel. There are similar considerations with shopping, and making household or personal purchases, or following the alternative pattern of allowing sighted persons to perform these chores for them. An important activity, not only in terms of obtaining nourishment, but also for its symbolic role, particularly in carrying on normal social intercourse with family and friends, is eating. Thus, since blind persons array themselves in a continuum from total independence in eating, while others want help in many phases, an index of independence in eating was included.

Description of Components

Employment: Strictly speaking, this component, the most heavily weighted, is not an employment index *per se*, since students and housewives were included. A series of questions were asked about employment at the time of the interview. The responses were classified to distinguish persons engaged in independent professions and competitive industry on the one hand, from those in sheltered workshops and traditional crafts associated with the blind on the other. The heaviest weight was given the first group, followed by the other employed. The unemployed were given no weight for this component.

Married women were classified by their score on an index based on an inventory of household skills, while students attending school full-time (mostly college), were arbitrarily assigned into the top group, on the grounds their current performance reflected an active, independent orientation comparable to the independent professionals and those engaged in competitive industry.

Travel Efficiency: This index was derived from three separate scales: Independence of travel; extensiveness of travel; and frequency of travel. The top third on this combined index were weighted most heavily, while the bottom group received no weight.

Independence in Shopping: Three items concerned with shopping were assembled into an index. These include: Does respondent shop for himself; Does he go shopping alone; Does he handle money. The scores were weighted in the same way as the travel efficiency index.

Independence in Eating: Seven items were cumulated into a score, and included questions on whether respondent eats alone in restaurants; if he asks waiter for help; whether he prefers to locate dishes for himself; does he prefer to identify the food by himself; if he wants someone to tell him where the food is on plate; whether he cuts the meat himself; and if he prefers to pour water, coffee, etc., for himself.

The scores for each person we reassembled and then grouped into four groups: I, the Independent Blind; II, the Moderately Independent; III, the Moderately Dependent, and IV, the Dependent Blind.

These four components are all positively associated with each other to a statistically significant extent, although the correlations are, in some cases, modest. One factor to take into account is the tendency for females, who were mainly classified by the household competence index, to dampen the correlations. Employment is a much more rigorous criterion of independence than the ability to iron, or cook, or to sew. Thus, travel efficiency correlates with the index of household competence with a modest C-coefficient of .13, while employment classification correlates .39 with travel efficacy. (see Table 1)

Primary Group Attitudes

If attitudes are significant for the blind person they must first be perceived by him. Thus, the information on attitudes is assembled from reports the respondent made on attitudes held by various persons he knows. The obvious danger is that this may simply reflect his own values, and thus we are only measuring the projected standards of our respondents. But a series of internal checks renders this hypothesis untenable, at least in a majority of cases. In fact, there is a great deal of variability in the attitudes they report in different sectors, such as travel or employment; and the different groups (family, friends--both sighted and blind--and employers), fluctuate from each other quite markedly. The projective hypothesis would only be consistent with

a great deal of similarity in an individuals report of the standards of different groups and in various behavior sectors. Then, the analysis (not reported here) was replicated, controlling for the persons own preferences, and the findings remain substantially unaltered. [10]

A series of questions were asked about the attitudes (or expectations) that the respondent perceived in four areas: travel, employment, sighted friends and taking care of one's needs. They were then asked how their families felt about this, their sighted friends, their blind friends and employers (if relevant). Thus, an individual can report there were four groups, three, two, one or no groups that favored independence. Some experimentation with different combinations showed that no predictive efficiency was obtained by combining all responses, so that only the responses to one item is used in this analysis: whether each group felt respondent can meet all his needs while making a trip.

In effect, we have an index of role-set, i.e. whether the persons with whom the respondent is in constant interaction, are agreeable in favoring independence; whether variable; or whether they tend to be fearful of the respondents ability to take care of his needs. [11]

The Predictor Variables

A sample of variables was selected that are ordinarily associated with adjustment not only for blindness, but for any other handicapped group (with the exception of residual vision). Each variable, with one exception to be noted, correlates with the adjustment typology. Sound reasons can be advanced for the correlations in each case; however, for this analysis they will not be pursued in detail, although each correlation obviously plays a significant role on its own. The variables were selected because they can be assumed to canvass a wide range of experience. These variables are of two types: (1) those reflecting background experiences significant for socialization or social group membership; and (2) those that are more clearly personal attributes of the blind person. [12]

The background variables include: education, age of onset of blindness, ethnic group and fathers occupation (as an indicator of social class origins).

The personal attributes used in the subsequent analysis are: vision, age, sex, and intelligence.

The Findings

Each of these variables is associated with the index of adjustment. For brevity, only the general pattern will be reported, mostly quite predictable from other studies of adjustment:

1. Those with higher educational achievement are more frequently found in Type I (Independent) than those with less education.

2. The earlier the onset of blindness, the greater the likelihood of an independent pattern of adjustment.

3. Blind persons who are white and of native born parentage are more likely to be independent than whites of foreign born parentage; Negroes, in turn, have the poorest distribution.

4. If parents held white-collar jobs, there is a greater tendency for independent adjustment than for the offspring of skilled workers; unskilled parentage is associated, generally, with modest or poor adjustment.

5. Blind persons with residual vision are more independent than those who have only light perception, or are totally blind.

6. Younger persons fare better than older blind persons.

7. As intelligence increases the proportion who are independent increases markedly.

8. Sex, because of the indexing procedure, shows no relation to the typology. It is included because it is a significant variable that plays an obvious role in the kinds of standards society is likely to establish, and is important in subsequent phases of the analysis of the data from this study.

The Test of the Hypothesis

The hypothesis states that each of the above variables predicts adjustment because each is a rough indicator of the attitude milieu faced by blind persons. We will examine first the relation of this attitude milieu, as evidenced by the number of groups that favor independence "to the adjustment typology"; this will be followed by an examination of the relation of attitudes in the milieu, as indexed by the number of groups favoring independence, and the adjustment typology, when the "predictor" variables are statistically controlled. If the hypothesis is true, the relation of attitudes and adjustment will hold up, despite the elimination of the influence of these predictor variables. If these variables were the significant predictors, the relationships suggested here would not appear. Thus, if younger persons, who generally report that the persons they interact with do not expect independence, they should be poorly adjusted, despite the generally better adjustment pattern of younger persons; similarly, older persons who report group standards of independence will in fact be independent more often, despite the tendency for older persons to be in the poorer adjustment category more often.

As can be seen in Table 2, there is a strong relationship between the number of groups that favor independent behavior, and the distribution into the adjustment typology. Where the respondents report no groups favoring independence, 16% are in the independent group; however, where 3-4 groups are reported favoring independence, 52% or more than three times as many are in the most independent group. At the other end, those with no groups to report are three times as often in the most dependent group.

The relationship in Table 2 is suggestive of the thesis that attitudes in the environment, as reflected by the number of primary groups that favor independence are significant for the achievement of independent adjustment by blind persons. As the number of such groups increases, there is a steady increase in the achievement of independent adjustment.

However, as noted in the list of various predictors associated with adjustment, a variety of such correlates can be located. The problem is to find whether these attitudes are significant in their own right for predicting adjustment. For example, what happens to a person who is at the unfavorable end of one of the predictor variables when the attitudes in his primary group are favorable?

For illustration, one sequence will be presented in tabular form; namely, the relation of education and independence. In Table 3, the proportion who report two or more groups favoring independence is indicated for each educational group, and for the several role-types. Note that approximately the same percentage who are Type I report two or more groups--from 53% for grade school or less, to 56% for those with at least some college. As the degree of independence declines, the proportion reporting two or more groups favoring independence drops down sharply. Thus, there is no important difference between each of the educational groups. However, the reason for the original correlation between education and adjustment can be observed by looking at the frequencies (in brackets): Those with little education are much more likely to report fewer persons expecting independence than college graduates (with high school in between). Three times as many persons are in Type III/IV among the less well educated than in the college group, where twice as many are in Type I. Despite college, if the "attitude" milieu is low, the adjustment is likely to be poor, and conversely for the less educated. If they encounter an environment that runs counter to the trend, they will achieve an independent level of adjustment. (see Table 3)

Table 3 presents, in tabular form, the same information presented in the graphs that will be examined shortly. The same data, presented in a slightly different way, will show, perhaps more clearly, how the original correlation arises when the "attitude milieu" is introduced into the picture. In Table 4 we see the association between education and adjustment as originally observed; it is clearly a strong and certain association, even if not perfect. (see Table 4)

However, if we examine the relation between the number of groups favoring independence and the typology of independence, within similar educational levels, there is a strong association. (See Table 5). One would expect, if in each segment of the table the groups have approximately similar educational attainments, the relationship between adjustment and "attitude milieu" would be attenuated. However, this is clearly not the case: Adjustment is still related to the number of groups favoring independence. This obtains despite the strong character of the association observed in Table 4.

From Table 5 it can be seen that the independently adjusted, irrespective of their education, tend to derive from primary group networks that favor independence, while the less well adjusted tend to report few or no such group reenforcement of independent behavior. Thus, the correlation of education with adjustment, despite its strength, cannot eliminate the influence of the attitude milieu. If education played a causal role, then the less educated would be in the poorly adjusted group irrespective of the number of groups favoring independence and it would be apparent in a lack of relationship between the number of groups favoring independence and the adjustment typology. Such is clearly not the case, however; the situation with the other "predictor" variables still remains to be examined.

To do this, a number of devices are available. A graphic presentation is resorted to that summarizes the results more compactly. (The data is in the form indicated in Table 3.) Thus, on the vertical or Y-axis we plot the proportion who report two or more groups favoring independence; and the degree of independence is on the horizontal or X-axis. If we plot, as in our above example, the less well educated blind on the graph, and the educated blind on a separate curve in the same graph, there are several possibilities. If the original association between education and adjustment was causally significant, we would find a slope that is parallel to the X-axis. On the other hand, if the relationship of education to adjustment is attributable to the number of groups favoring independence, we would find a descending curve; and irrespective of education, the two curves would roughly coincide.

Examining the enclosed graphs, it is seen that they are all similarly patterned. In each case, with inevitable aberrations, there is a trend for each of the curves to slope downward and to be roughly similar. Thus, for each of these variables, when the influence of the "attitude milieu" is controlled, the initial relationship tends to disappear. For education, vision, age of onset, age, sex, ethnic group, father's occupation and intelligence, a similar pattern emerges: To a large extent, these indexes function because, for one or another reason, they reflect the group standards the blind person encounters in his day to day interactions. The effectiveness of these predictor variables declines markedly when the attitude milieu is also examined simultaneously. (See graphs in Figures 1 and 2.)

Several explanations are possible to account for this, and later studies will be made to sort out some of them, at least. Obviously, reference group theory suggests some direction for further analysis; and, as well, the contribution a blind person's own behavior may make to the formation of attitudes among persons with whom he engages in social relations. Still, this is an impressive range of variables to behave in such a markedly uniform way including such standbys as education, intelligence and class origins.

The evidence appears to support the significance of attitudes, as these are perceived by blind persons, and their contribution to adjustment differentials. It is clear that this is a vital area for concern and suggests, first, that even a difficult prognosis, as estimated by the classic predictors of adjustment, can be bypassed. Second, it also points up the need for more effective work with families and friends of blind persons in order to maximize the potential adjustment of blind persons, and the development of methods to engage those who are in primary social intercourse with blind persons.

Examining attitudes in conjunction with adjustment, rather than as objects of study in themselves, points up their significance. As some investigators have suggested, with little more than their own experience to deal with, attitudes are likely to be crucial. While other factors are significant, they tend to influence the adjustment of blind persons through the attitudes that tend to be associated with these factors. At least part of the predictive power of the usual factors associated with adjustment is accounted for by their function as indicators of the environmental press that surrounds the blind person.

TABLE I

C-COEFFICIENTS BETWEEN COMPONENTS OF ROLE TYPOLOGY

	Indep. in Eating	Indep. in Shopping	Travel Efficiency	Occup. Classif.
Indep. in Eating		.26***	.45***	.20**
Indep. in Shopping			.33***	.17**
Travel Efficiency				.24***

** $.02 > p > .001$

*** $p < .001$

TABLE 2

NUMBER OF GROUPS EXPECTING
INDEPENDENT BEHAVIOR:

Adjustment	None	1-2	3-4
(Indep.) I	16%	33%	52%
II	27	31	23
III	33	27	17
(Depen.) IV	24	9	8
	100%	100%	100%
	(243)	(135)	(120)

TABLE 3

NUMBER OF GROUPS FAVORING INDEPENDENCE & ADJUSTMENT CONTROLLING FOR EDUCATION

	Adjustment			
	I (Indep.)	II	III/IV (Depen.)	
	Proportion Reporting at Least Two Groups Favoring Independence			
Completed Grade School or less	53% (34)	35% (31)	16% (119)	(184)
Some High School and H. S. Graduates	54% (68)	34% (73)	27% (77)	(218)
Some College through Post-Graduate Work	56% (46)	33% (30)	29% (17)	(93)

TABLE 4

DISTRIBUTION INTO ADJUSTMENT TYPES FOR DIFFERENT EDUCATIONAL LEVELS

		EDUCATIONAL LEVEL		
Adjustment		Completed Grade School or less	Some H. S. & H. S. Graduate	Some College thru Post-Grad.
(Indep.)	I	18%	31%	50%
	II	17	34	32
	III	38	24	13
(Depen.)	IV	27	11	5
		100%	100%	100%
		(184)	(218)	(93)

TABLE 5

ADJUSTMENT AND NUMBER OF GROUPS FAVORING INDEPENDENCE;
CONTROLLING BY EDUCATIONAL ACHIEVEMENTS

	Less Than High School Grad.				High School Grad. or Greater		
	Adjustment						
Number of Groups Favoring Independence	(Indep.) I	II	III	(Depen.) IV	(Indep.) I	II	(Depen.) III/IV*
None	26%	50%	58%	80%	29%	46%	60%
1-2	26	36	27	15	32	25	24
3-4	48	14	15	5	39	29	16
	100%	100%	100%	100%	100%	100%	100%
	(66)	(70)	(98)	(60)	(77)	(63)	(49)

* Combined because of small number of cases in Type IV.

PROPORTION WHO REPORT TWO OR MORE GROUPS FAVORING INDEPENDENCE; CONTROLLING FOR VARIOUS FACTORS RELATED TO ROLE TYPOLOGY

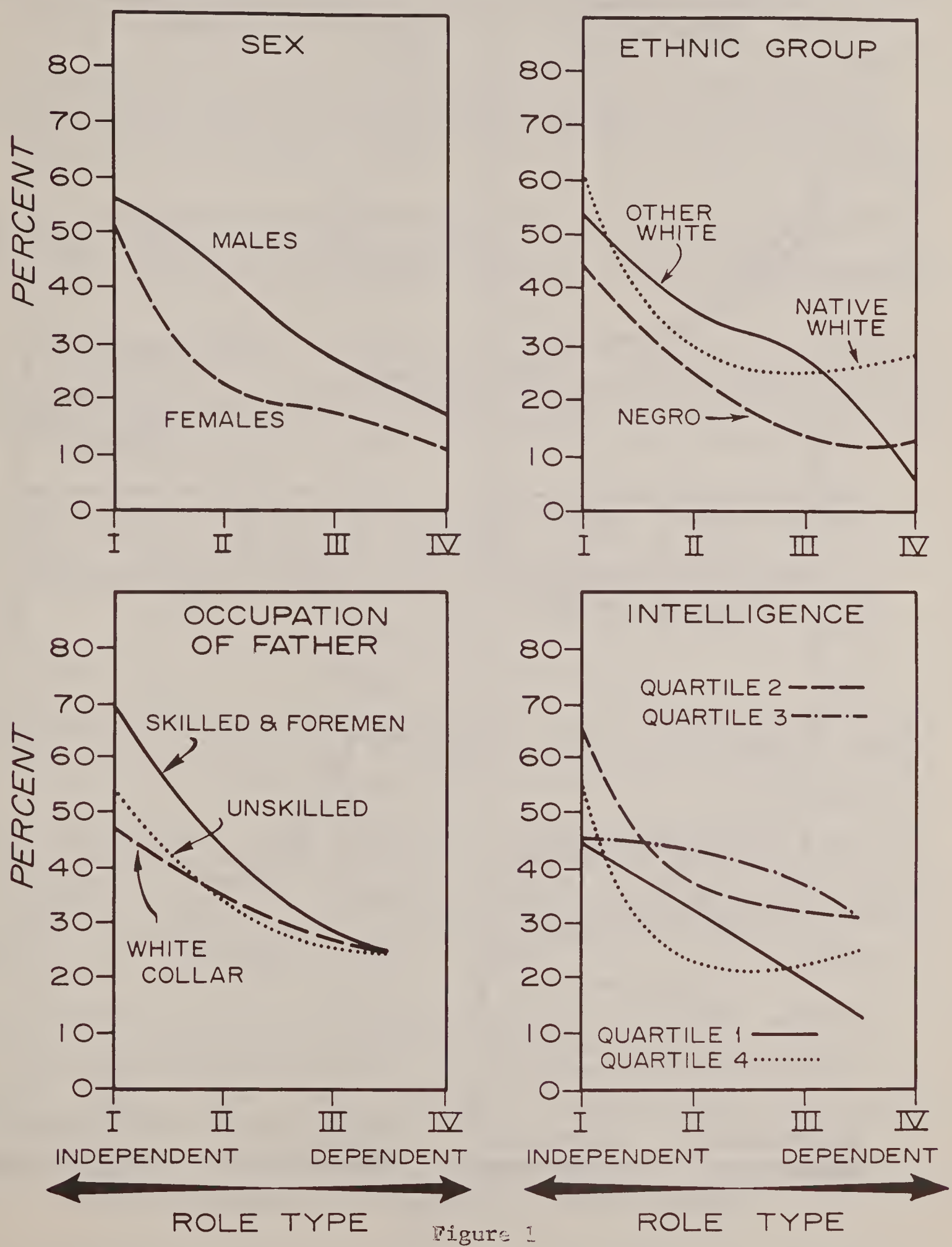

Figure 1

PROPORTION WHO REPORT TWO OR MORE GROUPS FAVORING INDEPENDENCE; CONTROLLING FOR VARIOUS FACTORS RELATED TO ROLE TYPOLOGY

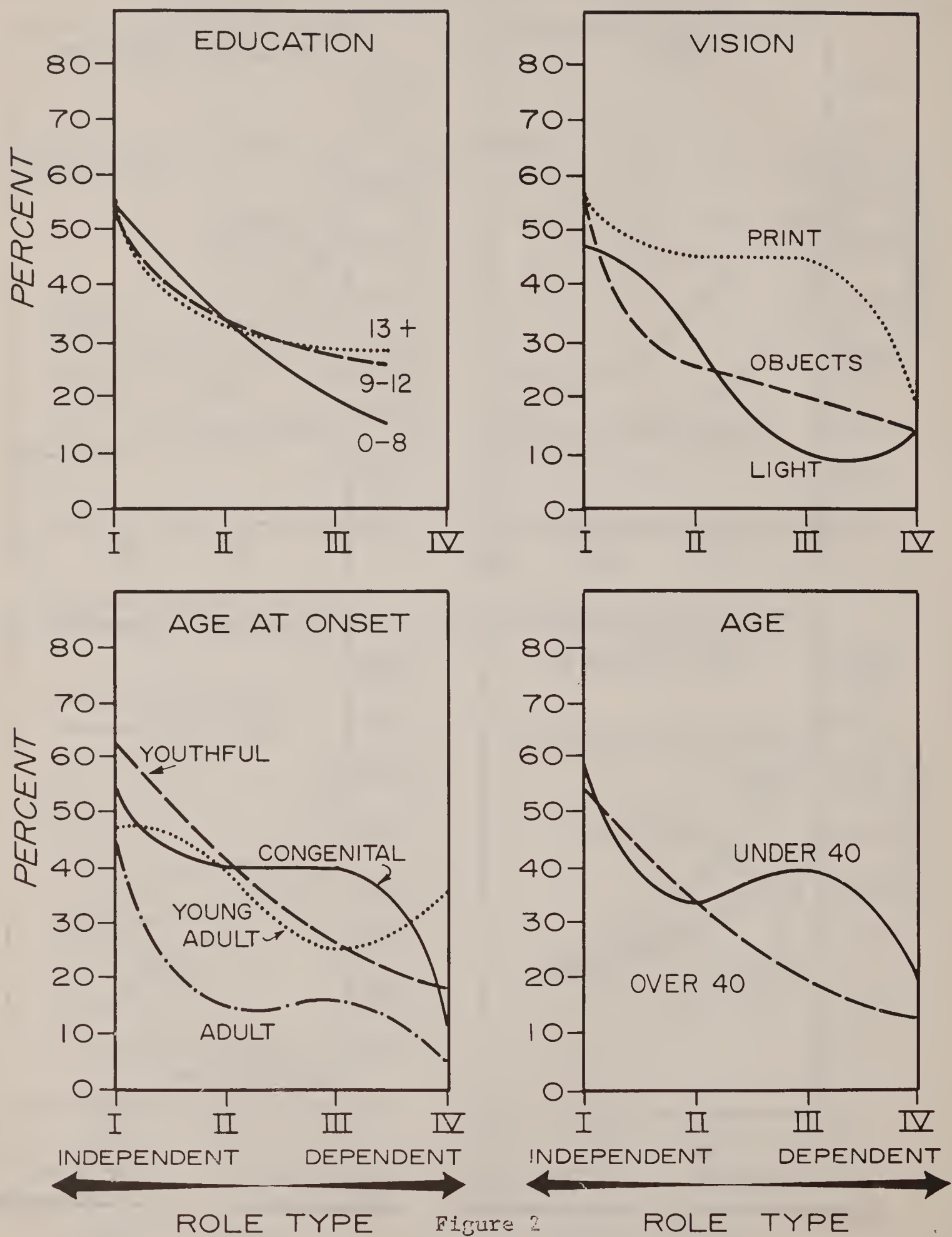

Figure 2

Footnotes

(1) In discussing thepsychology of blindness, the general thesis is that there is no special psychology of the blind, but a general psychology that can be focused on the problems that face blind persons. See Hector Chevigny and Syndell Braverman, The Adjustment of Blind Persons, Yale University Press (1956) pp. viii ff; Martin Whiteman, "A Psychological Appraisal of Blindness," pp. 45-63, in Social Casework and Blindness, S. Finestone (edit), American Foundation for the Blind, N. Y. (1960).

(2) A more detailed description of the sample can be found in The Demand for Dog Guides and the Travel Adjustment of Blind Persons, by S. Finestone, I. F. Lukoff and M. Whiteman, Research Center, NYSSW, Columbia University, 1960, Appendix A, pp. 104-112.

(3) A summary of extracts supporting this view may be found in Gowman, Alan, The War Blind in American Social Structure,N. Y.:AFB, 1957, Ch. 1; Twersky, Jacob, Blindness in Literature: Examples of Depictions and Attitudes, N.Y.:AFB, February 1955.

(4) See the typologies developed by Cutsforth, Thomas D., The Blind in School and Society, and Lukoff, I.F., "A Sociological Appraisal of Blindness" in Social Casework and Blindness, S. Finestone (edit). One "type" of adaptation is studied by Alan Gowman, op. cit., where he interviews independently oriented blind war veterans.

(5) See Whiteman, Martin, Lukoff, I. F., "Attitudes Toward Blindness - Some preliminary findings," Outlook for the Blind, Vol. 55, #2 (pp. 39-44); Cowan, Emory L. et. al., "The Development and Testing of an Attitudes to Blindness Scale," mimeog., 1956, (University of Rochester); Gowman, Alan, op. cit.

(6) See Gowman, op. cit. Ch. IV; Whiteman and Lukoff, op. cit.

(7) See War Blind Veterans in a Post-War Setting, Veterans Administration, 1958, U. S. Govt. Printing Office; Mary K. Bauman, Adjustment to Blindness, State Council for the Blind, Department of Health, Pennsylvania, 1954.

(8) The index of adjustment can be considered an index of social role, i.e., it characterizes the role performance of a blind person in a variety of fundamental social relations. Role also serves to direct attention to various useful hypotheses derived from role theory. In this paper, however, it will be identified as adjustment in order to confine the issues to a single hypothesis.

(9) For a more detailed description of each of the scales described below see S. Finestone, I. F. Lukoff and M. Whiteman, Appendix B. op. cit.

(10) A separate report will be made on a person's own attitudes and their relation to primary group attitudes and adjustment.

(11) A separate analysis, to be reported elsewhere, is made of the different groups, and their relative significance to the respondent's adjustment.

(12) This distinction is, in part, arbitrary, since some variables, such as age or ethnic membership may index both current "attributes" and background experiences. The classification is simply heuristic, and only a detailed analysis of each variable can settle the question of the appropriate classification.

PSYCHOLOGICAL AND SENSORY TESTS USED IN REHABILITATION CENTERS

Donald Blasch

At this stage it is foolhardy for any one person or discipline to believe that they have all of the answers to a safe, effective and efficient method of travel for the blinded individual. Not only are there various degrees of blindness, but what each blinded individual personally brings into the situation in terms of abilities, traits, beliefs and motivation, will in a large measure determine the success he will have in using any given modality to aid him in his mobility. It is, therefore, imperative that anyone working in this area be aware of, and use, all information pertinent to the subject from whatever source it is derived. The individual is not the sum total of all his component parts, but this does not detract from the fact that it is important to know as many of these component parts as possible to determine how they contribute or detract from the individual's attainment of his full potential in any area.

There are a multitude of psychological tests used by the various rehabilitation centers throughout the country, and the number and types used are in large measure governed by what information is desired, what tests are available that are suitable for use with the blind, and the personal preference of the psychological examiners. Basically, there are four general areas in which psychological and sensory tests can help in determining the subject's potential in the mobility area.

The first area can be generally classified as the physical and sensory capacity of the subject. Other disciplines have much to offer in this area and it is important to the psychological examiner to know their findings in order to make his examination more valid and meaningful. He should, for example, be cognizant of the results of the ophthalmological and auditory examinations and, as a result, may wish to alter the type of test given or vary the test procedure. The same may well be true if he is aware of the results of the neurological and general physical examination. The knowledge of whether or not the subject is on medication can also be important in helping him to make a useful contribution in this area. The tests that many rehabilitation centers use to augment the information in this area are primarily manipulative in nature. The old stand-bys are the Minnesota Rate of Manipulation and the Pennsylvania Bi-Manual Worksample. Others in use, although somewhat less extensively, are the O'Connor Finger Dexterity Test, Purdue Pegboard, O'Connor Wiggly Block, and the Hand-Tool Dexterity Test. I realize that these tests are primarily used to judge vocational potential and aptitude, but they can also give a good indication of the kinesthetic, motor skills, and orientation abilities of the subject. All of these are important in judging his potential as a traveler even though the testing takes place in a relatively sedentary situation and may not appear to apply when the individual moves about. The potential, however, is there.

Intelligence has always been considered to be an important factor in assessing a blinded individual's travel potential. I believe that this has been over-exaggerated and I seriously doubt that there is a high correlation between intelligence categories and independent travel efficiency, if we exclude the subnormal categories. I do believe that certain factors of intelligence, like sensitivity to comprehension and ability to make associations and to retain information are valuable assets in mobility.

The two tests most commonly used to measure intelligence are the Hayes-Binet (used with children) and the verbal portion of the Wechsler-Bellevue Adult Intelligence Scale. A considerable amount of work has been done in developing a performance portion of the Wechsler at the Illinois Institute of Technology. The University of Purdue is validating an intelligence test that will also depend less on verbalization and more on performance. When finally standardized and validated these should prove to be a big help.

Going on the assumption that a stable emotional and personal adjustment is an important factor in judging the adaptability of a blinded person to orientation and mobility situations, there are a multitude of tests that can be used for this purpose. Mary Bauman's Emotional Factors Inventory is specifically designed for the blind adult and is probably the best of the objective tests. Others in general use are the Minnesota Multiphasic Personality Inventory, the Bell Adjustment Inventory, California Test of Personality, Personal Index and the Bernreuter Personality Inventory. There are many more. All are primarily designed for sighted individuals, but by a few revisions are suitable for use with the blind. Unfortunately, they usually measure some distinct traits and personality cannot be measured as the sum total of distinct traits. Projective techniques used to overcome this deficiency are not as yet a reasonably reliable measuring instrument in this area. Projective techniques, the best known being the Rorschach and the Thematic Apperception Test rely on visual stimuli. In the area of the blind the stimuli must come through the remaining senses, primarily auditory and tactual. The senses of smell and taste are seldom used. Tests used here are the Twitchell-Allen, (three-dimensional), Tautophone (interpreting records unclearly played), Musical Revue (episodes or series of images from music), sentence completion, word association, etc. I am sure that a blinded individual that is emotionally stable and mature will do considerably better than one who is immature, insecure and unstable, other factors being equal. Quite often transitory emotional states will momentarily affect travel performance and I believe that individuals who are physically aggressive and slightly impulsive have a better chance of becoming good travelers. All these factors can be determined by a careful interpretation of the tests in this area.

Measurements of motivation and readiness, which are essential factors in the acquisition of skills and techniques, are more difficult to obtain. There are no established and validated tests in this area. Yet a high degree of motivation can do much to alleviate deficiencies in other areas and it enables one to perform to the capacity of his potentials. Motivation can be instilled; it may be transitory in nature; it may fluctuate in intensity; it may be affected by emotionalities, but it still remains as one of the most important factors in achieving success in any area. Since there are no reliable or validated measuring devices in this area it must be done on a subjective basis. I feel that a careful review of a longitudinal case history, plus a relaxed psychologically-oriented interview with a period of observation will give you a good indication of the subject's level of motivation and his readiness to participate in a rehabilitative process.

I am sure that there are many other tests used in various rehabilitation centers. Many have been developed by the individual center and their use may be confined to that center. These are usually tests confined to checking tactual perception (usually using various grades of sandpaper) and the checking of the gait and neuro-muscular coordination through a series of predetermined physical activities.

There is a great deal of information that can be derived from the psychological and sensory tests, but they are of little value if confined solely to the subject's folder and used only by the psychologist to write his reports. All too often the only information that other therapists wish to know is the subject's I.Q. and this is one area that can be inhibited by emotional reactivity to a task that involves danger to the body i.e. mobility activities. All test results should be interpreted by the examiner and then disseminated by him to the people working with the subject.

In the final analysis it is the skill and knowledge of the instructor teaching the skills and techniques that has the most to do with success or failure of the subject's learning. The faith that he has in what he is teaching, the better qualified he is by training and personal qualifications, and the greater the knowledge of the subject whom you place at his disposal, the better the results will be.

Transmission Systems For Skin Sensation

Dr. Patrick D. Wall

There are two questions, I think, that somebody faced with a pressing practical problem such as we are discussing here today, could reasonably ask a physiologist. One of them would be, "Given the absence of one sense, what would you suggest as the rules for translating one sense into another?" The other obvious question is, "What about regeneration -- why doesn't regeneration occur?" Actually these are not unrelated questions.

With respect to the first question, let me say something that seems obvious but is often forgotten, namely that the nervous system has a design. This is not intended as a metaphysical statement. I mean simply that the nervous system is an apparatus which has been evolved to handle particular problems.

You know that it is relatively easy to improve a dog's efficiency at hunting rabbits, but very difficult to get him walking on his hind legs. The same thing applies to the skin sensory system. Why set it a task equivalent to a dog walking on its hind legs, when there are much easier things to teach it? For example, transient phenomena are generally much easier to detect than steady state phenomena. Moving things are easier to detect than stationary.

Physiologists have come to realize that you cannot properly study a system such as the sensory system by adhering to the traditional methods of investigation employed in physics, chemistry and mathematics. These are subjects in which the question of teleology does not arise. One does not ask what an electron is "for", or what a number is "for". With a motor car or a piece of the sensory nervous system, however, your questions will be rather fruitless until you do ask what it is for.

Let us examine for a moment what happens when a sudden pulse is injected into the nervous system. Take for example a sudden flash of light which uniformly illuminates the whole visual field. We may think of this as a simple stimulus, that is, one whose intensity, duration and so on, can be easily described in well-defined physical terms. To the nervous system, however, a flash may be the most complex stimulus possible, containing any possible aspect of any possible stimulus.

The response to such a stimulus seems quite simple in the first stages. You observe a certain change in nervous activity and a more or less exact image of this change is passed along from stage to stage, as in a simple relay transmission system. In other words, you have a simple isomorphic translation of the stimulus relayed from station to station and finally deposited in the brain.

Clearly this is inadequate. There must somehow be a decoding mechanism. Physiologists have long avoided the question of where this analysis occurs simply because they saw no signs of it. Recently however, through the use of natural rather than artificial stimuli, it has been discovered that these relay stations are not relaying simply, but are filtering out particular constellations of events.

Physiologists are understandably excited in having begun to locate where these analyses take place. This work is of course not complete, and there are as yet no answers of practical value that were not previously known to psychologists. Let me emphasize again that with respect to choosing modes of translation, you must design your translation system with regard to what the particular system was evolved to handle, rather than your notion of what might be the most efficient system for, say, a mechanical analyzer to handle.

Let us move on now to the question of substitution of a sensation by stimulation within the nervous system and this question of regeneration. To begin to answer this question you must first ask in what terms information is transmitted from one place to another. There are two opposed theories about this. The one that is always described in the textbooks is that of a simple "fire alarm" system. This theory says that there is a point, say, on the tip of the left index finger that responds only to touch and that this information is carried through a channel in the nervous system and ultimately connected to some central map which recreates the outside world in terms of the particular modality.

One usually thinks of three types of information that must be carried over this channel: the nature or modality of the stimulus (touch, pain, cold, etc.), the location of the stimulus and the intensity of the stimulus. The transmission of intensity is considered relatively simple. But the transmission of modality is especially difficult to understand without reference to some sort of analyzing function, which this classic theory seems to avoid.

The opposing theory says that the particular connections comprising the channel are relatively unimportant and that what is important is the analysis of the nerve impulse pattern in time and space. The impulses are coded and there are central analyzers decoding this bombardment of impulses in terms of time patterns and space patterns. These two patterns will determine the nature and location of the stimulus.

One of the few laws in biology is that if you can think of two opposing theories and begin looking around in the nervous system, you will almost certainly find both of them in action. This is precisely what has been found. There seem to be signs of both a "fire alarm" system and a time-space coded system. Neither theory seems to be wholly adequate. Let me cite just two rather dramatic examples.

First, in examining the transmission pathways of skin sensation, we have been quite unable to find any cells at the first central nuclear region that might be called pain cells, that is, specific cells that are fired only by a stimulus which provokes pain. Secondly, it appears that all the cells that transmit temperature information also transmit pressure information. Certainly the animals we are dealing with are capable of distinguishing pressure from temperature, yet the two types of information seem to be coming over the same pathway. These two examples, then, would seem to militate against the theory of a "fire alarm" system.

On the other hand, in the problem of transmitting information about stimulus location, there are indications that support this theory.

It is really a question of level. Everyone admits that some sort of "fire alarm" system exists in the gross. For example there are nerve fibers that unquestionably transmit visual information exclusively and others that transmit auditory information exclusively. The question is whether the theory is also valid at the microscopic level. Some people have good evidence that the minimum resolvable point in the visual field, for example, is represented on a central map in the visual cortex. A natural question then is, "Why not stimulate the visual cortex, thereby getting directly at the map itself?"

Unfortunately, there are a number of practical problems involved. Some are just mechanical ones. First of all the cells are very small. You must get close to them to stimulate them and getting close to them destroys them. Here you have a sort of biological application of the indeterminacy principle. Secondly, there is the possibility of a mixture of the time and space code between different channels, which means you would have to encode the stimulus in the proper time and space sequence. This complicates the problem greatly. Incidentally this is why an electric shock stimulus can never be made to resemble any common sensation. An electrical stimulus applied to the skin produces a very unusual time and space pattern of nerve impulses and does not really resemble any other sensation with which you are familiar.

This problem of signal distribution, if you will, is precisely what we are faced with in regeneration and transplantation. That is, the connections must make some sense. If regeneration occurred at random, each fiber making connection with the first available cell, the system probably would not work. No detailed information could be transmitted across such a nervous system.

There are two further obstacles to regeneration however. One is the formation of scar tissue. When a portion of the brain is damaged, the area of damage is filled with scar tissue just as a skin cut fills with scar. This tissue represents a simple mechanical barrier to further reconnections. Transplantation between men is prevented by antibody production. Up to now this has been the main obstacle to skin transplants, except between identical twins. Fortunately, this is a problem that is quite well understood now and the possibility of actual cross-grafting does not seem quite so remote.

But even if the problems of scar tissue and antibody production could be solved, we still have not answered the question of how regeneration might be controlled so that correct connections are formed. The most common hypothesis is that each nerve fiber has its own chemical specification and will unite only with its complement. The notion that each of the millions of cells in the retina has its own chemical specification and will unite only with a complementary cell in the brain, may be the most convenient explanation of how the nervous system grew in the first place and of how regeneration occurs in certain species of amphibia, but it is certainly an awesome prospect for an investigator.

There is some hope, however, in that the grain may not be as fine as suggested, and that the space-time patterns may not after all be too complex to reproduce. These studies of experimental regeneration in the amphibia are in a very exciting and at the same time frustrating phase at present. The big question seems to be whether there is an exact chemical matching of the fibers or whether there is a possibility that some learning, so to speak, takes place in the matching of these elements. It is one of the most exciting problems and may well contain an answer to some of our questions about possible regeneration in the human.

A COMPARISON OF HUMAN AND BAT AUDITORY SYSTEMS

Alan D. Grinnell

Whereas human beings rely primarily on vision for orientation, the bat relies primarily on hearing. During the last 50 or 100 million years, while we humans have been developing a highly specialized sense of vision, many bats have developed an arsenal of very sensitive auditory equipment. Their expertness in echolocation is well known and leads one to hope that the study of this remarkable ability in bats may lead to useful applications for humans handicapped by blindness.

Bats display certain obvious morphological adaptations for the utilization of sound. The pinna, for example, is always large, often enormous. In Plecotus, the long-eared bat, it is more than half as long as the rest of the body. Another feature peculiar to the Chiroptera is the tragus, arising in front of the external meatus and pinna, which looks something like a reflector in a parabolic horn, though we do not know whether it has this function. The bat's ear then is qualitatively the same as most other mammals, but it is highly specialized quantitatively. The tympanic membrane is much the same, as is the middle ear construction; but the ossicles are extremely light and have articulations permitting unusually tight "welding together" of the whole chain. The cochlea is very large, particularly in the basal turn, and relatively somewhat longer than in most other mammals. The auditory brain is very highly specialized. Poljak, the histologist, was so impressed by the bat auditory system that he selected it as a model for study of the mammalian auditory system.

It is interesting to compare the brain structure of a non-echolocating fruit-bat and an echolocating relative, such as our common little brown bat, Myotis. In Myotis the posterior colliculus, which is one of the way-stations in the auditory system, is very much hypertrophied, as are all the more peripheral auditory centers. In man, on the other hand --- as in the non-echolocating bats --- , it is the anterior colliculus and other visual nuclei that are enlarged. Zworykin, in comparing the volumes of the peripheral auditory nuclei in bats as opposed to non- echolocating animals, found that they are from 6 to 100 times larger in the bat than in the human, relative to the rest of the brain-stem, both in cell count and volume.

Since bats are so specialized anatomically, one would expect them to be physiologically specialized as well. We have been studying how the bat responds to sound and to small changes in sound by means of electrophysiological recording. Using an uninsulated gross electrode in the colliculus, one can record positive evoked potentials from all the auditory centers, those from distant centers being transmitted by volume conduction. In such recordings, we find four prominent response peaks which arise in the auditory nerve, probably the cochlear nucleus, probably the superior olivary complex, and finally at the lateral lemniscus and colliculus. These potentials, which represent an average of the responses of a large population of elements around the electrode may be the most meaningful criteria for what the animal actually listens to in the sound.

We presented a variety of stimuli --- pure tones, clicks, noise --- but most often a short pulse of pure tone, rising and falling gradually so as to eliminate most of the transients. The pulses ranged from 0.5 msec. to about 10 msec.--- not much different from the sounds the bats themselves emit. Consider now what the bat must do. He must detect the presence of an object, determine its distance, its direction and its location with respect to other nearby objects. Detection first requires the ability to hear the frequencies in the echo. Myotis emits frequencies sweeping from about 100 kc down to 20 kc, Plecotus from 45 or 50 kc to 25 kc. We have found excellent correlation between the ranges of emitted frequencies and the ranges in which the bats' hearing is most sensitive. Myotis, for example, is most sensitive from 20 kc to 80 kc --- the same range in which most of the sound energy of the emitted pulses is found. Plecotus has a unique "audiogram" showing two regions of extreme sensitivity, one near the fundamental and the other at the frequencies of the second harmonic. This high range of frequencies is the first real difference in hearing between bats and other mammals. In using these high frequencies, the bat can of course obtain much finer resolution of the very small objects in which he is interested.

Bats are exceedingly sensitive, too, to small changes in both frequency and intensity. In experimenting with frequency changes we found that a change of only 1 kc often resulted in an almost complete response where previously there was none. This is not equivalent to a change between 1000 cycles and 2000 cycles in the human range, which would be a very large difference, but is a change between, say 49 and 50 kc, which is very small. In another experiment, we recorded evoked potentials in response to 23 kc tone pips in which the intensity was changed in 0.1 db steps between 59 and 60 db with resepct to the usual reference level of 0.0002 dyne/cm^2. Noticeable differences in response can be seen with changes of only 0.1 or 0.2 db. The comparable differential intensity threshold in man is about 0.5 db at high intensity, 5 or 6 db near threshold.

The successful detection of very small objects seems even more remarkable when you realize that the bat must be sensitive to an echo which is considerably fainter than the emitted cry and which returns immediately afterward. The echo from an object 3 feet away, for example, returns about 6 msec. after the beginning of the emitted cry. As the bat approaches very near an object, the echo returns in less than a millisecond. This recovery ability, the ability to resolve and analyze sounds coming at such short time intervals, constitutes a second difference between bats and humans. The human being listening to two clicks from a single external source does not really distinguish them as two sounds until they are about 10 msec. apart, at which point the second sounds much fainter than the first.

The bat's recovery at the level of the auditory nerve, which I have designated N_1, is about the same as in cats. Response begins after about 0.4 msec, rises to 50% recovery in 2 to 3 msec., and continues to rise until it reaches 100% recovery in 30 to 100 msec. In cats, recovery is slower and slower with ascent to higher neural levels. In bats, however, recovery becomes much faster at higher neural levels. At N_2, which probably represents activity of the cochlear nucleus, recovery is complete in about 2 to 5 msec. At N_4 (the collicular response) there is often 100% recovery and somewhat greater amplitude in the second response after only 1 to 1.5msec. This is approximately an order of magnitude faster than man is capable of subjectively, or a cat electrophysiologically.

Recovery at the various auditory levels is dependent both on intensity and frequency. At 50 or 60 db above threshold, recovery is very slow. At lower intensities, response becomes better and better until at 10 db above threshold the response is typically supranormal. It has also been observed that increasing the frequency in the signal hastens recovery, and that changes in intensity have a greater effect on recovery at higher frequencies.

In addition to detection, bats also have the problems of range finding and localization. With respect to range finding the simplest hypothesis would be that they measure the time elapsed between pulse emission and returning echo. Since they respond so well from about 0.5 msec. on, it seems reasonable to expect that if they can measure these intervals they can determine distance. Other evidence exists which strongly supports the view that single cells in the brain can do this.

The remaining question, then, is how do they localize an object? We know reasonably well how human beings do it under controlled conditions. They use one or more of three different cues. At low frequencies, differences in phase at the two ears are used for discriminating angle of incidence. This may be interpreted as difference in arrival time for transient phenomena. At high frequencies, however, intensity differences seem to be the criteria used. Bats using such high frequencies and having such a small interaural distance (about 1.5 cm.) probably do not use phase or time of arrival. Humans under ideal conditions can distinguish differences in arrival time as small as 10 microseconds. The same angular deviation interpreted by the human as a 10 microsecond delay would be interpreted by the bat as a one microsecond delay. We have no evidence that the bat is capable of this sort of resolution.

Another criterion that the bat might conceivably use is the simultaneous difference in frequency of the echo returning to the two ears when the reflecting object is away from the midline. At most it would be a 50 cycle difference, however and while this may be easier to interpret than a one microsecond time difference, the two are probably equivalent operations and equally unlikely.

This leaves us with the criterion of intensity differences at the two ears. These are measured in our experiments by moving a loudspeaker around the bat in the 180 degree horizontal azimuth and recording the thresholds at each of the 13 positions 15 degrees apart. In doing this we find that each ear is very directional. The input from each ear goes largely into the opposite side of the brain. Thus if one is recording from the left colliculus, the ear which is most sensitive is the right ear, and vice versa. In recording thresholds we find that this directional sensitivity is a function of frequency. As frequency increases from 20 kc to 50 or 60 kc, the intensity difference between the directions of maximum sensitivity and minimum sensitivity increases to about 60 db in some cases. The difference goes up rather sharply for Myotis between 25 and 40 kc, then levels off at a total change of about 40 db on the average. It is very interesting that Myotis, with small ears, is much more influenced by frequency at 30 to 40 kc than is Plecotus, which increases sharply in directionality at 40 to 50 kc. This is somewhat unexpected in view of the much larger Plecotus outer ear.

Although these intensity differences may result primarily from sound shadows caused by the geometry of the head, it is difficult to accept this as a sufficient explanation, especially in the more extreme cases. We have in fact performed experiments which show that binaural interactions are taking place whereby input to a colliculus from the contralateral ear is actually inhibiting input from the ipsilateral ear, thus sharpening the apparent directionality and making the response appear to come more and more completely from the contralateral ear. It is probably safe to say that a bat is capable of distinguishing direction on the basis of this directionality of the two ears, if it is indeed capable of making 0.5 db intensity discriminations. This intensity change would correspond to an angular change in the horizontal plane of one degree or less.

I have attempted to give you a brief description of what kind of auditory information the bat must be interested in, and something of the methods he uses or might use to obtain that information. The results of our experiments with bats must of course be compared with further research in the human senses before any practicable solutions can be found to the problems faced by the human who must rely on the senses other than vision.

MOBILITY WITHOUT VISION BY LIVING CREATURES OTHER THAN MAN
(WITH SPECIAL REFERENCE TO INSECTIVOROUS BATS)

Frederic A. Webster

I. INTRODUCTION

The guidance systems used by animals are commonly divided into two broad classes: active and passive. Echolocation methods, such as the pulsed orientation signals of bats and porpoises, are examples of active systems. Vision, passive listening and infra-red sensing are passive systems in the sense that the energy providing the stimuli specifying environmental features is not emitted by the animal itself. [21] Many examples of both classes are to be found throughout the animal kingdom.

The creatures most familiar to us, perhaps, as being not only extraordinarily mobile but capable also of incredibly rapid and precise maneuvers under non-visual guidance are the insectivorous bats. As far back as the 1790's Spallanzani observed no loss of skill or capacity for orientation in bats that were blinded. Almost a century and a half had to pass, however, before the bat's technique was known to be echolocation. [2,5,6] Now we recognize the bat's system as a marvel of speed, precision and relative infallibility -- a system pre-eminently deserving of extensive study.[26] But before embarking on a discussion of the bat's methods, and their relation to the activities of man, we should briefly review the methods of some other creatures.

Sonar-type guidance* is probably employed to some extent by many animals, though it appears to be most highly developed in the porpoise and various other cetaceans.[13] The porpoise, like the bat emits pulsed signals of high frequency sound and interprets the received echoes. If the size of the acoustical analyzing system in the brain is an indicator, then the porpoise should be capable of unravelling far more complex echoes than the bat. Unfortunately, discovery of just what a porpoise does with its analyzing system under natural conditions is extremely difficult, and hence most of the porpoise's true capabilities and methods remain unexplored.

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*Sonar originally designated: SOund NAvigation Ranging (or SOund NAvigation And Ranging) is defined in Webster's New Intercollegiate Dictionary as:"An apparatus that detects the presence and location of submarines, underwater mines, or the like, by means of inaudible high-frequency vibrations which are reflected back to it from the objects". But according to Horton [11] the term "sonar" now implies: 1) systems whereby underwater acoustic energy is used for observation or for communication, 2) the principles and practices employed in the design and operation of these systems, and 3) the branch of applied acoustics identified with the utilization of water as the propogating medium. The common feature of the various definitions is transmission and use of underwater signals, chiefly of a vibrational nature. The bat's signals are air-borne, and are, according to accepted use, not in the realm designated by the term "sonar." Since they consist of energy in acoustical form rather than electro-magnetic, they are also excluded technically from the realm of RADAR: RAdio Detection And Ranging. However, because common principles frequently apply to all echo-ranging systems, echolocation techniques in air are legitimately called "sonar-like" or "radar-like." The most suitable specific term for the acoustical echo-ranging systems of animals is "echolocation."

Another creature that uses pulsed acoustical signals for three-dimensional orientation is the South American Oilbird, Steatornis.[4] Using much lower frequencies, and far less deftly controlled by their indications, this bird (and certain other birds also) can nevertheless navigate successfully in caves that are totally dark and can locate roosting places without the use of vision. Water beetles of the genus Gyrinus [5] also use active echolocation, but of a rather different order. These small animals generate disturbances along the two-dimensional surface of a pool and determine the position of obstacles by interpreting the reflected ripples. Interpretation of effects from induced vibrations is undoubtedly widely used by animals for partial evaluation of spatial relations in the immediately surrounding area. In some instances, as we have seen, the method supplies almost total guidance relative to the outside world.

A different type of active detection or guidance is found in three separate families of fish, and must have been independently evolved within each family. These fish all emit electrical discharges and analyze the nature of the electrical fields produced. [14,15] Not only is position of objects at close range usefully determined, but the structure and properties of nearby objects sometimes ascertained with remarkable precision.

For a long time the question of whether blind people, and perhaps other living creatures, "feel the presence" of nearby objects has been under debate.[5,12] Singularly lacking in the work in this area are adequate experiments on the role of air currents, notably those that may be actively induced. It seems quite likely, for example, that a bat or a bird may govern its close range elevation above a surface of water in considerable measure by "feeling" the cushion effect of its wing beats or tail motions. Kinesthetic senses may detect the slowing down that occurs with the increased resistance to motion close to the surface. Tactile changes, temperature shifts and modification of differential pressures on the wing or tail surfaces may also contribute to such evaluation.

The realm of non-visual guidance by passive means is too extensive a subject to deal with here. Outside of vision, auditon and touch, most sensations probably serve chiefly to alert or warn -- though certainly the well-directed sense of smell of a dog does an excellent job of tracking and localization. Mention should perhaps be made of the infra-red sensing of certain snakes. [1] Direction of prey can apparently be determined with sufficient accuracy to govern fully effective strikes. In the case of vision, of course, huge amounts of coding are done in the retina, so that the messages reaching the optic areas of the brain are meaningfully simplified and organized. Transformations and interactions actually characterize all the sensory pathways and help shape the incoming messages into meaningful and usable patterns.

This introduction should not be concluded, however, without stressing the important role of the internal integrating and orienting systems which stabilize the frame of reference into which external orienting impressions feed. Without the constant action of the kinesthetic and vestibular systems, external orienting stimuli would be to a large extent chaotic and meaningless. Of this, more will be said later.

II. ECHOLOCATION PROBLEMS OF THE BAT AND THEIR RELATION TO HUMAN ACTIVITIES

Because most of our detailed studies have dealt with the echolocation problems and techniques of insectivorous bats, the remainder of the discussion will pertain to bats and to the relation of their techniques to problems of human orientation. As a starting point, we take four activities of human beings and see what we can learn from a transfer of the method of guidance from visual to acoustical means.

A. A Review of Four Human Activities Akin to Those of the Bat.

The first activity is simply ordinary day to day travel and object location. Since these more usual problems of acoustical guidance have been dealt with extensively elsewhere,[28] the present review will be very brief. At a distance, most configurations of interest are two-dimensional, but at close range they are largely three-dimensional. At a distance, echolocation by usual means, such as foot step echoes, is largely ineffective, whereas at close range -- except in the presence of noise -- it is extremely useful. Certainly the fall-off in effectiveness of many acoustical indications, with increasing distance, is vastly more rapid than is typical of visual indications. Obviously, the mismatch between the visually designed world of human beings and the requirements of a blind person becomes accentuated with distance, and evaluation of such items as general route, distant traffic configurations and desired direction of travel may become extremely difficult.

At close range, barring specifically visual tasks, the mismatch tends to be more easily resolved, though there is little relation between the importance of the problem and ease of solution. One way of classifying the bulk of close-range problems is into the three categories: 1) general orienting configurations, 2) specific positive items, and 3) specific negative items. Inside a building, for example, a person has to: 1) evaluate doorways, stairs, furniture arrangements, etc., 2) beware of step-downs, step-ups and aerial obstacles such as open cup-boards, and 3) locate such useful items as: typewriter, telephone, brief case or clothes. Patterns of sound, both actively generated and passively detected, are commonly effective; and the use of touch is normally accessible. Since details of these problems and the instrumentation for their solution are dealt with elsewhere, no further discussion is needed here.

The second activity we intend to look at is the piloting of an airplane by auditory reference alone. At the end of World War II a project known as "Flybar" was set up to develop a conversion of the indications required for routine airwork from visual to auditory reference.[17] Basically, the indications were for: a) turn, b) bank and c) nose elevation of the aircraft. For example, when the nose of the simulated airplane (a Link Trainer) went up, the repetition rate of a sequence of pulses went down, in imitation of a slowing motor. Direction and rate of turn were indicated by the apparent direction and rate of motion of a tonal sound that seemed to rotate around the head. During the course of the tests several different kinds of experimental sounds were fed into the pilot's headphones to indicate the three airwork actions; but the results, from a practical point of view, were somewhat disappointing. Despite attempts to provide natural-seeming indications of the aircraft motions, interpretation by the pilot was not easy, much attention was needed, confusion readily occurred and extensive learning was sometimes required.

Moreover, while certain additional information was given through the earphones, a great deal that a totally blind pilot would want was omitted. For example, further airwork indications, such as heading, airspeed, altitude and rate of climb, would be needed. Second, a number of additional orienting items would have to be provided: position with reference to destination, local flight pattern requirements, specific and reliable landing guidance, etc. Third, the pilot would need certain weighting and warning indications, both with respect to the external situation and as regards the aircraft and its powerplant. Weather conditions, potential obstacles and fuel supply are obvious examples. And fourth, there would often be additional instructions and data he would want. While much of the data listed above could be given verbally, certain additional control indications would clearly be in order.

Undoubtedly, a systematic improvement and extension of the "Flybar" plan, under modern instrumentation and aircraft guidance systems, would make safe and oriented flight by a totally blind pilot perfectly feasible. In practice, however, such a procedure would probably be accomplished not by feeding all the data through the pilot, but by bypassing him. Completely automatic flight has now been in existence for some time, and under such conditions the pilot becomes chiefly a monitor.

Since the present analysis is concerned with guidance by auditory reference, we must return to the blind pilot as the controlling system and inquire about the inadequacies of the "Flybar" system. The first point we note is that despite efforts toward natural indications, the signals used were poor sensory guiders for complex servo-type control actions. They required conscious interpretations and they were cumbersome and confusing. The second point we note is that, as tested in the "Flybar" situation, the auditory channels (or the associated processes of resolution, interpretation or motor integration) readily became overloaded. Adequate control of an aircraft during complicated aerobatics or in complex configurations of obstacles would have been impossible. Yet these are exactly the conditions under which a bat is so swiftly and precisely guided by its auditory system.

This brings us to the third activity, namely acrobatics by a blind trampolinist or perhaps by a blind tumbler. Such activities are characterized by rapid and radical changes both in translational position and in rotational position and action. Position, velocity and acceleration, involving up to six degrees of freedom,

may be rapidly shifting simultaneously. But the situations cover rather short integration times and are executed with reference to large and static external configurations. While applicable methods of auditory guidance have thus far been little studied, it is clear that an adequate system would in many ways fall closer in line with the bat's methods than did the methods used in the "Flybar" experiments.

Perhaps the outstanding consideration in the present illustration is the need for adequate linkage between the two broad systems of guidance: the systems for external guidance (namely audition, vision, touch and kinesthesis involving external contact) and the systems for internal guidance and coordination (chiefly the vestibular and kinesthetic systems). The former are poor indicators under rapid and complex accelerations and must, in effect, be momentarily switched out of the control mechanisms. The latter are very precise and effective under rapid and radical accelerations, but the precision decays rapidly under extended integration times; and false indications often appear. Of utmost importance, therefore, are effective internal-to-external linkages at the junction zones where external reference must be very rapidly re-established under the combined guidance of internal indications and the external frame of reference. Since disorientation increases quickly with discrepancy, one may well suspect that the bat has excellent internal control mechanisms and that the echolocation system is highly adapted for the rapid re-establishment of effective external linkages.

The final activity to be discussed is tennis by a blind player. In contradistinction to the previous illustrations, the most essential linkage here is to a small object (the tennis ball) which is rapidly shifting in position. At the same time, the player must execute translational motions within a defined field (the court) and must achieve proper manipulative aim with good predictive anticipation. In other words, the player must stay approximately in the court, must judge where the ball will be at a certain time, must get there and must hit the ball with suitable aim at the right time and position. The analogy with the catching techniques of bats is less far fetched than may at first sight seem, for bats do commonly have to remain within a zone defined by obstacles, predictively evaluate the trajectory of a small moving object (flying insect), get to the correct spot at the right instant, and accurately retrieve the moving target with the bent-over tip of an extended wing.[16,27]

When we ask how we might adapt the game of tennis to auditory reference, certain features immediately become evident. Most obvious, perhaps, is the great variation in frequency or specificity of the data samples demanded by the player at different instants. For example, much of the time the player would not need detailed indications about the court or the opposing player. Intermittent indications of high data rate, or constant indications of low data rate, would suffice. Thus one type of sound source along the net and another slightly different type along the sides or back line, together with some indication of the action of the opposing player, would probably provide all the information needed. By contrast, the information content of indications about the ball would have to be much greater. But again, the density, content and frequency of the information required would vary enormously from situation to situation.

Consider, for example, certain times at which rapid and accurate assessment of external data becomes essential. When the ball is hit by an opponent, a player wants to know immediately what action to take. But if the ball, after being hit, is travelling relatively slowly toward a far corner, he has little need for continued high-precision data. If his initial prediction is good, and his general orientation adequate, then his internal guidance system will take him to the correct zone at the correct time and will also facilitate the re-establishment of good acoustical linkage with the moving ball. Just before hitting the ball, however, he will need a dense sampling of precise and compelling data.

What kinds of acoustical linkages to the ball might be useful? Passive methods might include a uniform buzzer within the ball, or perhaps a buzzer in the ball that had a repetition rate varying with air speed -- or one that gave a momentary burst proportional to the speed with which it was hit. Here, the intensity of the pulsed sounds reaching the player would vary approximately as the inverse square of the distance between ball and player. Suppose, however, that active echolocation were used. Here the player might wear a directional speaker on his head and wear headphones that permitted both active and passive signals to reach him binaurally. The active echolocation signals might be some type of ultrasonic pulse, the returning echoes of which would be translated down into the effective range of human hearing. If the intensity relations of the returning echoes were preserved, intensity would now vary as the inverse fourth power of distance*, thus providing sharper close-range indications interpretable in terms of relative distance, direction and velocity.

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* Intensity does not vary strictly in inverse ratio of the fourth power, since size, shape, texture and mass of the target introduce differences as a function of frequency. Atmospheric attenuation also varies as a function of frequency: amounting to roughly 2 db per meter at 50kc and 3.5 db at 100kc. (See Reference 5, Chapter 14.)

Possible instrumentation for active echolocation by pulsed signals brings up a number of important questions. For example, what should be the time relations between the emitted pulses and the expected echoes? A basic consideration here is whether or not the returning echo should overlap the outgoing pulse, [19, 20] and how transmission and reception should be adapted for both overlap and non-overlap if both cases were expected. Should the transmitted pulse be totally gated out of the reception system, or should part of it be retained? Should some representation of the pulses be multiply translated in time for direct comparison with the echo? Should the pulses be of constant duration, or should the length vary inversely with expected distance (that is, roughly with echo delay)? If overlap between transmitted pulse and returning echo is expected, how might the overlap indications be made most effective?

Any attempt to answer these questions immediately poses questions about the structure of the pulses themselves. Should they be pure tones, harmonic sounds, random noise or clusters of impulse functions? Should they be of uniform composition or of varying composition within each pulse and perhaps from pulse to pulse? Moreover, since echoes from small objects at some distance are weak, and subject to interference by noise and clutter, what aids can be provided in the form of indications received passively? These are all questions which would be of major concern in the instrumentation of blind tennis; but since they are of primary concern in the bat's system of acoustical ranging, discussion will be deferred until the bat's methods are reviewed.

What have we learned from this survey of possible adaptations to auditory reference of activities that are normally guided by vision? Of the general observations perhaps two were outstanding, namely 1) the existence of certain rather gross mismatches between a visually designed world and the requirements of a blind person-- mismatches which, in the realm of spatial orientation, tended to increase with distance, and 2) the lesser channel capacity of auditory control of action-- particularly where several independent control loops were involved. While many of the problems of mismatch may be solvable by suitable instrumentation and training, the lesser capacity of the auditory system may sometimes introduce serious limitations. The skills of acoustically guided animals suggest however, that much can be done by optimum utilization of the capacities available.

With respect to the specific activities, a number of relevant details became obvious. In normal day to day orientation and action, it was clear that a hierarchy of importance or primacy existed in both negative and positive directions. Thus, for example, unexpected step-downs and aerial obstacles are strongly negative. Yet in a visually designed world their detection by an acoustically controlled individual may be difficult. Most acoustical indications, moreover, fall off more sharply with increasing distance than do the corresponding visual ones. And, barring pea soup fog, visual indications tend to be less susceptible to interference.

In the review of problems facing the totally blind pilot, we gained the impression that the human auditory system was designed more for the analysis of certain types of complex signals than for their immediate use in multi-dimensional control loops. Clearly, when higher levels of the auditory system had to parcel out different portions of an acoustical signal into different control loops, confusion and disorientation were likely to result. The effectiveness of high-speed auditory control of complex maneuvers in some animals, however, suggests that effective control might also be achievable in man; but that more effective utilization of natural auditory devices would have to be developed.

The illustration of the blind trampolinist emphasized the unsuitability of external senses for the maintenance of orientation under radical and complex accelerations, in contradistinction to the adequacy of the kinesthetic and vestibular systems. But because the accuracy of internal systems ordinarily fell off sharply with time, rapid and effective linkage between internal and external systems had to be re-established frequently. Since the insectivorous bats perform violent and complex maneuvers, yet maintain excellent acoustical orientation, they must maintain good synchronization of indications from the two systems, and their signals must facilitate very quick establishment of acoustical reference at the end of violent maneuvers.

As regards the blind tennis player, the chief problem was how to obtain a high density of suitable data about the trajectory of the ball at certain critical times. For example, immediately after being hit by an opposing player, the ball's trajectory would have to be accurately known in order to permit suitable preparation; and again, just before returning the ball a player would require very accurate data in order to carry out suitable action with the racket. A signal system that adapted itself to the phase of action seemed to have advantages; yet it was clear that many possibilities for actual implementation would have to be assessed before a blind tennis player could be provided with optimum guidance. The highly effective system of the bat, for a rather similar set of problems, seemed likely to provide useful clues.

B. A Review of Some Problems for the Signal System of a Bat

Just as a blind individual must find his way around, and recognize objects and configurations by auditory reference, a bat must achieve rather similar results with the aid of audition and other non-visual senses. [26] For example, a bat must: 1) get from its day time roosting place to water, to suitable hunting areas and to good resting spots, 2) evaluate adequate pathways through rather intricate spaces in woods, bushes, caves and attics, 3) avoid specific small and injurious objects such as thorns and twigs, and 4) find specific configurations and objects of value. Like the blind aircraft pilot, a bat must be able to transform configural indications, given acoustically, into effective flight paths in three-dimensional space. At the same time, the bat must be able to modify its path according to priority items of danger or need without becoming disoriented with respect to the total configuration. In order to maintain orientation while executing the very high-speed and violent maneuvers required for the interception of some flying insects, the bat must have excellent kinesthetic-vestibular (internal) guidance and -- like the blind trampolinist -- must be able to re-establish

very quickly the required acoustical linkages to essential objects and configurations. Finally, as with the tennis player, the bat needs extremely accurate, compelling and readily usable data on small targets in order to achieve precise high-speed interceptions on flying insects. We must now see how the signal system of insectivorous bats may facilitate the handling of these various problems.

III. THE ORIENTATION AND PURSUIT SIGNALS OF INSECTIVOROUS BATS

From what has been said thus far, certain requirements of the bat's echolocation system have become evident. Perhaps the following five requirements are among the most outstanding:

1) The echolocating signals must simultaneously serve a number of purposes or functions, and must also be rapidly adaptable to momentary requirements demanding special emphasis, such as close-range as against far-range detection.

2) They must permit detection of small objects and fine details of structure.

3) They must provide for rapid and accurate guidance of interceptions on small air-borne targets of variable trajectory.

4) They must facilitate rapid establishment of oriented reference at the end of violent maneuvers.

5) They must be resistant to jamming and clutter interference, permitting the capture of small targets close to intricately shaped objects (such as leaves and pine needles) that give far more prominent echoes.

The exacting requirements of the signal system of insectivorous bats might lead one to expect that evolution would have produced one optimal echolocating technique with only minor variations in basic pattern among the various families. Of considerable interest, therefore, is the fact that different families of bats exhibit widely differing echolocating signals. Indeed the only conspicuous common features are: a) pulsed form, b) ultrasonic frequency range and c) tonal or harmonic carrier structure. Even these attributes show remarkable variation.

Pulsed Form. All bat signals are pulsed: they occur in definite blocks of sound with silent periods between. However, pulse duration, pulse repetition rate and duty cycle vary enormously both in a given species of bat at different instants and between different families of bats.[5, 18, 21, 25] In the greater horseshoe bat (*Rhinolophus ferrum-equinum*) pulse durations commonly vary from 100 milliseconds down to 10 or so, with corresponding repetition rates ranging from 2 or 3 per second to somewhere in the order of 40. Duty cycle often exceeds 75%. By contrast, the widely scattered Vespertilionidae of the temperate climates show a markedly different pulse structure. Maximum duration is about 10 milliseconds (about one-tenth the *Rhinolophus* maximum), maximum repetition rate is commonly around 200 pulses per second (about five times the *Rhinolophus* maximum), and the duty cycle typically runs in the order of 10%. In some species, the pulses seldom exceed 2 milliseconds. The pulse structure is certainly so different as to suggest quite different modes of operation in the echolocation mechanisms.

Ultrasonic Frequency Range

Detailed structure of the individual pulses also shows marked variations both from family to family and from phase to phase of activity in a given bat. Fundamental frequencies range from approximately 100,000 or 120,000 cycles per second down to about 20,000 cycles per second or somewhat less, but a single pulse may contain both variations of the fundamental and variation in harmonic proportions. The signal of the greater horseshoe bat is a pure tone of extraordinary constancy (at about 85 kc) throughout most of its duration, while the signal of most of the common Vespertilionidae may drop approximately an octave in frequency during each pulse. During insect pursuit the frequency range within each pulse may slide down from the 100-50 kc range to the 30-20 kc range, or it may be approximately preserved at the higher range during all maneuvers. Except in young bats, however, the signals remain almost exclusively in the ultrasonic zone.

Tonal or Harmonic Carrier Structure

The pulses are made up of simple sinusoids, or sinusoids with one or two harmonics. They are not, for example, hiss-type noise or single clicks. The appearance of harmonics, however, is sometimes striking. A fundamental of 40 kc will give a first harmonic at 80 and a second harmonic at 120 kc -- this being roughly the highest frequency in common use by bats. Both theoretical considerations and actual observations suggest that frequency dispersal in the signal may be very useful. Indeed its lack in the major portion of Rhinolophus pulses appears to have required the evolution of special techniques in the echolocation mechanisms. As already indicated, the frequency dispersal is commonly achieved by the use of frequency sweep, by the use of harmonics or by a combination of both. The use of a marked frequency sweep provides not only large bandwidth but also an ordering of frequency relations which the bat can effectively use. In the handling of typical echolocation problems, bats characteristically shorten the outgoing pulses so as to avoid, or almost avoid, overlap between the returning echo of chief interest and the outgoing pulse. In fact, some gap between signal and echo is typical. This fact has given rise to the "time-to-echo" postulate of range determination.

The long almost-constant-frequency pulses of Rhinolophus, however, seem to relegate time-to-echo measurements to a less prominent role. It is true that most of these pulses show a slight frequency drop at the end and that this may help provide a basis for the measurement of the time of signal termination for comparison with the time of echo termination. But the relative infrequency of such terminations would greatly reduce the possible extent of such use. Most echoes of interest clearly come back while a pure tone signal of constant frequency is being emitted, and evaluations of range, azimuth, elevation and perhaps relative velocity -- as well as other attributes, such as size, structure and wing beat -- must be made out of the interaction patterns of outgoing pulse and echo.

Certain additional features of the Rhinolophus mechanisms of echolocation are outstanding. Besides their length and pure tone quality (at a rather high frequency), the pulses have a high intensity level and are probably more sharply beamed than the average frequency-swept pulse.[21] This beaming is achieved in part by emission through the two nostrils, of half wave length separation, in conjunction with a rather wide conical nose-leaf structure. But the ears, also, appear to play an extremely prominent role in the evaluation of echoes. The ears can be aimed together in one direction, can be moved and modified in shape independently, and are frequently subject to an out-of-phase alternation in synchrony with pulse emission. As a bat approaches a landing place, or evaluates nearby objects from its roost, it may vibrate its ears--with the left 180° out of phase with the right--at 30 or more times a second, while emitting pulses at approximately the same rate. Just how these various mechanisms are integrated into the echolocation system is a complex one that calls for further investigation.

Other Attributes

Besides the variations in pulse length and rate, pulse carrier frequency and carrier harmonics and frequency sweep, there are other notable variations between the signals of different bats. Most conspicuous among these, perhaps, are differences in intensity. Griffin notes that bats "...which feed on fruit or large sleeping animals rely on pulses having 100 to 1000 times less energy..." (Ref. #5, p.251) than typical bats that feed on flying insects. But the very large eared Plecotus rafinesquii, also intensively studied by Griffin,* emits pulses of intermediate energy level: about 20 db below most bats of the same zones which apparently feed on a rather similar population of insects. Why should a bat evolve such low intensity pulses when the large ears required for adequate detection of echoes must be physically cumbersome? In one set of experiments we noted that Galeria moths, which possess an auditory system capable of hearing the approach of most bats from some distance, often failed to evade a Plecotus that came up from behind--or dodged only at the last instant. The same moths would not fly at all when Myotis were present. Possibly there were other attributes of the Plecotus signal, such as lower frequency or different repetition pattern, which supplemented the non-evasion effect observed in moth catches by these bats. The evidence certainly suggests that the low intensity pulse may be designed in part to forestall awareness of pursuit by the victim; and the long evolutionary history of moth vs. bat strategies gives testimony to the importance of this issue.[22,23,24]

Other differences occur in the signals of insectivorous bats, but such variations are often subtle, complex and certainly inadequately explored to date. Of these, one of the more obvious is the variation in pulse repetition pattern seen in different bats and in different situations. Some kind of primitive pulse code modulation or pulse position modulation may aid in unravelling the intricate echo structure that obviously exists when several bats are flying simultaneously in a complex space giving many echoes from widely scattered distances and directions. Further details are beyond the scope of the present discussion.

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* See refs.9 and 10. Further work on Plecotus is in progress.

This brief survey of variations noted in the signal structure of echolocating bats suggests that a number of different practical solutions may exist to typical echolocation problems. In the final section we intend to illustrate the successful solution of one particular problem -- the capture of one of a pair of catapulted mealworms -- by one particular bat, Myotis lucifugus. This illustration, while interesting and significant as a representative example, does not speak adequately for the many techniques of different bats around the world in solving a highly varied assortment of echolocation problems.

IV. AN EXAMPLE OF ECHOLOCATION

Space prevents any adequate discussion of the manner in which a bat may govern the nature of its echolocating signals and put the detected echoes to work. Actually, most of the details remain a mystery; so the best we can do in concluding this rather broad review is to focus briefly on the shifts in signal structure that occur as one particular bat achieves a successful solution to a specific physical problem.

Figure 1 shows the general relations during the execution of a successful interception and catch of a mealworm by the little brown bat, Myotis lucifugus, during the summer of 1959. In this instance two mealworms were projected upward from below into the approximate path of the bat. The solid line shows the path of the bat, while the broken lines represent the trajectories of the targets. Above the solid line a sequence of drawings are given. These are tracings from a series of multi-flash images made of the bat during the approach and catch, to show the details of the bat's actions. The numbers (F-1, F-2, F-3, etc.) along the line correspond to the sequential numbers of the images, and represent approximately the position of the bat's mouth at the time of each flash. Stereo cameras were actually used so as to provide accurate evaluations of spatial relations, but the tracings are from one camera. A synchronous sound recording was made, and the position of the pulses along the path of the bat calculated for the distances and angles of the path as shown. These are indicated as numbered marks on the upper side of the path-line of the bat.

The general relation of the emitted signal to the physical situation is fairly clear from this diagram. Though no pictures were taken during the early portion of the approach, lines have been placed at previous positions to show approximately the relation of signals and physical situation. These lines represent the approximate path of the bat's signal from mouth to targets and back to the ears. In the existing experimental situation, it was difficult to judge where detection[8] took place inasmuch as the bat normally increased its pulse repetition rate when it expected a target. Certainly such targets are clearly detected by the time a bat has reached a one meter distance; and it is just about at this point in the present approach that the pulse repetition rate shows a definite -- if irregular -- increase. This is about 1/3 of a second before the catch.

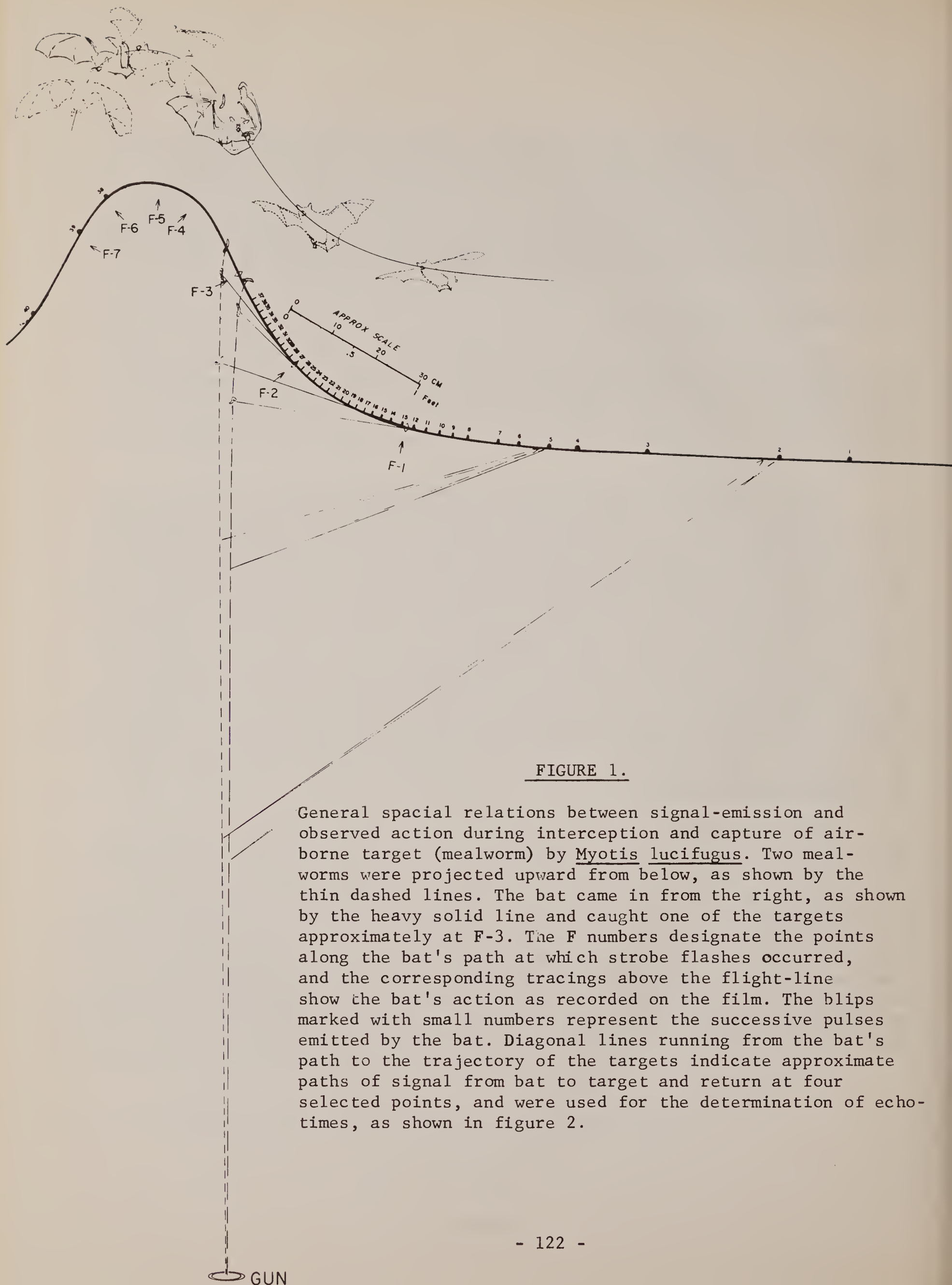

FIGURE 1.

General spacial relations between signal-emission and observed action during interception and capture of air-borne target (mealworm) by Myotis lucifugus. Two mealworms were projected upward from below, as shown by the thin dashed lines. The bat came in from the right, as shown by the heavy solid line and caught one of the targets approximately at F-3. The F numbers designate the points along the bat's path at which strobe flashes occurred, and the corresponding tracings above the flight-line show the bat's action as recorded on the film. The blips marked with small numbers represent the successive pulses emitted by the bat. Diagonal lines running from the bat's path to the trajectory of the targets indicate approximate paths of signal from bat to target and return at four selected points, and were used for the determination of echo-times, as shown in figure 2.

The pattern of the pulse structure noted in this approach is quite typical [7] -- though many variations are seen as a bat deals with the highly varied interception problems of normal hunting. After a somewhat irregular increase in repetition rate, there comes a brief transition zone characterized by a definite increase in rate which in turn leads into the final "buzz": a regular sequence of short pulses at about 190 per second. Here there are about 20 such pulses, covering roughly one foot of travel, and ending a few inches short of the catch itself.

The bat's technique of catch needs a word of explanation.[27] A bat normally attempts to bring its tail membrane forward just prior to the catch and to center the target in the pouch so formed. Immediately, the membrane is brought over the mouth and the target seized by one end. If the bat cannot easily make the requisite approach, it reaches out a wing and sweeps the target into the pouch for seizure. Occasionally the target is caught on a foot and pouched. The present catch was complicated by the existence of two targets within 3 or 4 inches of each other - a separation which is difficult for a bat to resolve. One target was about 40 mm. above the other and about 100 mm. nearer to the camera. The bat apparently aimed more or less between them and did not turn its head to the nearer target until after it hit the left leg or the inner membrane of the wing (roughly at flash #3). It at once turned its head left, went into the pouch and seized the mealworm. A quarter of a second later (flash #5) the bat had resumed flight, with the worm in its mouth, and was emitting pulses.

Crucial to the bat's echolocating technique, as suggested earlier, is the relation between a given pulse and the received echo of primary interest. Figure 2 is traced from an oscilloscope film of the pulse sequence for this catch. In order to give some idea of the relations between the successive pulses and the corresponding echoes from the two targets, the approximate positions of sample echoes are indicated. For the sake of clarity the echo from one of the targets is shown above the base line and that from the other target below. It is evident that the pulses are successively shortened so as to leave roughly a millisecond between the termination of a given pulse transmission and the peak of the echo. This applies, at least, until the terminal buzz -- the final rapid sequence of pulses, each of one-half to one-third of a millisecond in duration. Pye [19] has suggested that overlap might provide a highly effective measure of range; and there may be conditions where intentional overlap is used. In the present instance, however, overlap appears to be definitely avoided.

Many details of bat pulses and their shifts with different physical situations must be left to other discussions; likewise many features of bats' techniques and the differences between different types of bats have been omitted.

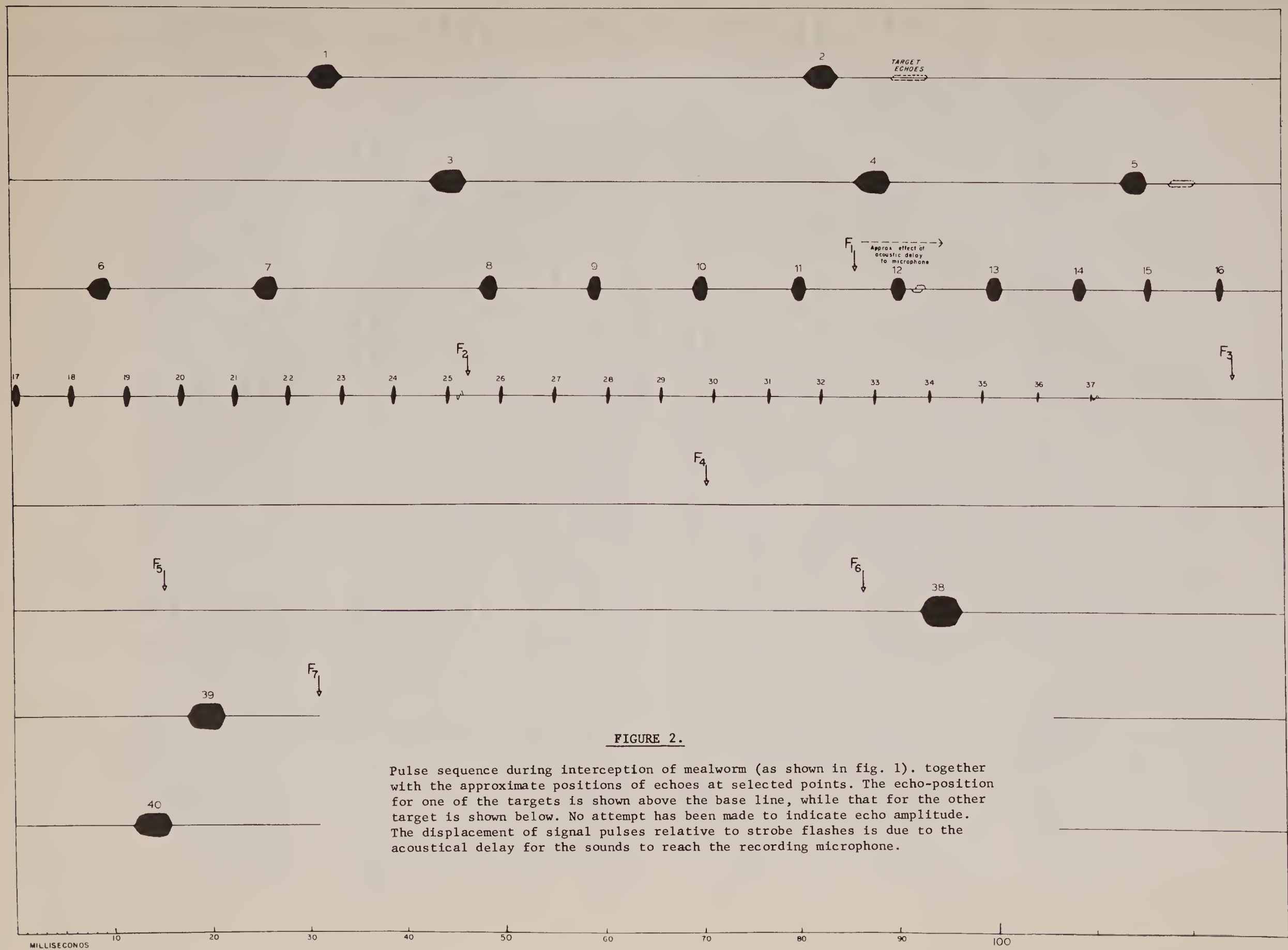

FIGURE 2.

Pulse sequence during interception of mealworm (as shown in fig. 1). together with the approximate positions of echoes at selected points. The echo-position for one of the targets is shown above the base line, while that for the other target is shown below. No attempt has been made to indicate echo amplitude. The displacement of signal pulses relative to strobe flashes is due to the acoustical delay for the sounds to reach the recording microphone.

Of unusual interest, for example, is the matter of a bat's capacity to predict trajectories. The present illustration shows little prediction in that the bat follows the targets upward, in a pursuit type of course, rather than aiming directly for the closest possible point of interception. But the issue here is confused by this bat's preference for a climbing catch. Remarkably good predictive interceptions of fast falling mealworms have been noted in wild red bats, Lasiurus borealis, and in some Myotis lucifugus trained in the laboratory on ballistic trajectories.

While not evident in the present illustration, the chief feature about a large proportion of insect catches by bats is the extraordinary speed, precision and reliability of response. If bats had some super-fast electronic device to carry out the interception calculations, one might not be so astonished at the bat's capacity to detect, locate, intercept and catch two insects within a second. [7] But the bat is a mammal with a mammal's inherent limitations in speed of neural processing and of motor response. Moreover, it is a mammal with a remarkable life span for its size -- up to perhaps 25 years. Were the bat not able to evaluate its surroundings quickly and well it could not long survive; and, at the high flight velocities of some bats, would surely meet with frequent and serious injury. Yet a bat achieves all these feats without effective vision and with a processing system little larger than the tip of a pencil. We consider it pre-eminently worthwhile to find out something of how a bat can do so much, so fast with so little.

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ELECTRICAL STIMULATION OF THE SKIN *

Dr. Robert Gibson

One evening not long ago I walked with my eyes closed down the sidewalk of a busy street in Pittsburgh. The one block journey was rather erratic. I bumped into a few people and buildings, nearly went off the curb twice, but finally made to the end. An impressive amount of auditory information was available to me, information that in such a situation is normally suppressed or not processed by the central nervous system. This led again to wondering to what extent one might be taught to use cutaneous information. If only we knew what to listen for and how to listen for it cutaneously.

The problem of replacing unavailable visual or auditory information with tactile information is not simply a matter of better natural listening by the skin. Ordinarily there is little if any cutaneous counterpart to the wealth of visual and auditory stimuli that normally accompany moving autos, people, etc. Vision and audition are distance senses; touch is not. If the skin is to read out information ordinarily sensed by the eyes, some translation is required into a form suited to the characteristics of the cutaneous sensory system. The basis question then is, What kinds of cutaneous displays will enable information to be effectively processed by cutaneous channels? Our answer to this question naturally depends on our knowledge of the ability of humans to discriminate various aspects of cutaneous stimuli.

It is ironic that our great present-day engineering facility, although responsible for certain advances in this field, may also have provided an obstacle to such progress. Many of the problems of skin communication have been conceived as engineering problems, without sufficient regard for the sensory characteristics of the human. The result, a mismatch between instrument and sensory system, is often an engineering triumph but a psychophysical and therefore a practical failure.

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In the 1930's, R. H. Gault and others tried to bypass the ear by converting speech into mechanical vibrations applied to the skin. A well practiced subject could recognize the speech of only one speaker and after 30 hours of practice could identify simple single words only half the time.[2] The skin is simply unable to discriminate small changes in frequency of vibration in the range necessary to understand spoken speech. The optimal frequency range for skin discrimination of rate changes is ten times lower than that for the ear. Thus, by solving certain engineering problems, we might do a passable job of tactually reading speech at one-tenth normal rate, if we had the time to listen.

More recently, Wiener, Wiesner, David and Levine at the Massachusetts Institute of Technology attempted to follow Gault in directly transcribing spoken English into a cutaneous language. (See M. I. T. Research Laboratory of Electronics Quarterly Progress Reports, 1949-51 under Sensory Communications: "Felix".) They took advantage of the power configuration of speech and alternating currents were led to the skin through a filter network of seven channels. Although perhaps sound from an engineering standpoint, the system depended on characteristics of speech and did not respect the natural dimensions on which the skin is able to make discriminations.

In 1957, Professor Frank Geldard at the University of Virginia took the other tack. He began by asking what sensory dimensions were available from which a cutaneous language could be built. Howell's results showed that a subject could receive messages through an array of chest vibrators at more than 35 wpm.[4] Location, intensity and duration of the vibratory stimulus were the variables comprising the code. This is a faster rate than proficient Morse, but still only 1/6 the rate of slow speech.

However, there are drawbacks to using vibrators for cutaneous communication. Vibrators are bulky, inefficient, and do not respond well to rapid changes in the temporal characteristics of the stimulus. Under suitable conditions, sensory information similar to that from vibration may be supplied by direct electrical stimulation of the skin. By contrast with vibrators, electrodes are small, perfectly reliable as transducers and may be attached to many body areas without regard for cosmetic problems. Also, with certain stimuli subjective localization is much better than with vibrators, providing the advantage that a greater number of perceptually distinctive locations on a given body area are available for coding purposes. With the proper size electrodes and the appropriate waveform, an electric stimulus can provide the same intensity as a mechanical transducer and require less than 1% of the power. Since electrodes also have good frequency response characteristics, electrical stimulation of touch, using often less than 50 milliwatts of power per stimulus, conveniently provides wider potential variation of the temporal character of the stimulus.

In order to find whether cutaneous channels are effective other than as providing mere unidimensional warning information or slow literal translation of speech, one needs systematically to vary cutaneous signals along the temporal and spatial dimensions simultaneously in order to learn something about the resolving power of the nervous system for complexly-patterned stimuli. This is the basis of our current effort at Carnegie Tech, based on the success of the efforts I am about to report to you on pain-free electrical stimulation.

Pain and discomfort have long been associated with experiments in electrical stimulation. Research on cutaneous processes would be enhanced if this discomfort were eliminated. My remaining purpose here is to tell you something of the history of the investigation, and of conditions which lead to pain-free electrical stimulation of touch.

The use of electricity in research on tactual sensitivity predates Helmholtz. For our purposes, however, it starts with the experiments of Schwarz in Germany in the 1940's. Schwarz [5] varied the frequency of an alternating current applied to the skin. Both touch and pain thresholds rose with frequency but at different rates, so that although threshold stimulation was invariably painful at perhaps 100 cycles per second, at a higher frequency, say 15 kilocycles, the pain threshold was well above the touch threshold and stimulation was not painful at moderate intensities. This suggested first that electrical pain and touch might be independent mechanisms, and second that the pain was in some way a function of the ac frequency.

When the frequency of a sine wave is increased, three properties of the stimulus vary. [3] Frequency itself varies, the amount of current per half-cycle decreases, and the rate varies at which current increases in each half-cycle. Since these properties vary jointly, their effects cannot be assessed separately as sinusoidal current. When electricity is presented as dc pulses, however, the effects of polarity, half-cycle width, frequency and perhaps rate of current increase can be measured separately since they vary independently.

In 1953, Sigel, reporting on clinical investigations, published qualitative results of stimulating the skin with long trains of electric pulses. [6] In 1957 Uttal, in his dissertation from Ohio State University, provided us with two things: a modern strength/duration curve for electrical touch, with a chronaxie that implicated large 'a' fibers as the site of action for electrical touch stimulation, and secondly the observation that brief electric pulses might stimulate touch without pain. [7] In 1958 Hahn, at the University of Virginia, repeated Sigel's work, with better control, using long trains of pulses to the fingerpad.[3]

His results confirmed Uttal's value for touch chronaxie, and added that touch threshold stimulation of the fingerpad with long trains of pulses depends on individual pulse duration and not on pulse frequency (repetition rate) within the range 60-5000 cycles per second.

The present experiments involve the notion that touch and pain thresholds, by responding differently on several dimensions of electricity, as boundaries define a "region" of reliably pain-free electrical stimulation of touch. We know at this stage that threshold stimulation of the foot and fingerpad is painless under a wide variety of electric stimuli. Further, threshold touch on the fingerpad with long pulse trains at medium to high cutaneous frequencies (60-5000 cps) depends largely on the half-cycle pulse width and not on the rate of pulse repetition. In order to find whether touch and pain differ as to their response to basic temporal properties of the electric stimulus, touch and pain thresholds measured as peak current were determined as a function of (1) the number of brief pulses, and (2) the rate of pulse repetition (at low rates). Pain and touch thresholds were obtained for eight body regions selected both for anatomical differences and for differences in the ease with which pain ordinarily accompanies electrical stimulation of touch.

Fig. 1 shows representative photographs of three stimuli, as displayed and measured on the face of an oscilloscope that is reading across a resistor in series with the tissue. Individual pulses are slightly greater than 0.5 milliseconds in duration, and in these pictures are separated from one another by three different time intervals. The bottom stimulus is composed of six pulses each separated from the preceding pulse by four milliseconds, a pulse repetition rate of 250 pps. The middle picture shows three pulses separated by 10 milliseconds, corresponding to 100 pps.

Single such pulses, arranged to stimulate only touch and delivered to the palm, fingerpad, or palate, "feel" not unlike a single tap from the blunt end of a fountain pen. The apparent area stimulated with single pulses through moderately sized electrodes is smaller than the electrode and nicely localized. The subjective area increases in extent with an increase in the number of pulses per train, and the perception takes on a temporal character analagous to pitch. Whether the character of the sensation resulting from stimulation with trains of such brief pulses in fact closely resembles "natural" cutaneous perception is unimportant. The idea was to find conditions for reliably stimulating a perceptually vivid cutaneous sensation that was readily localized, had a quick onset and subsidence (so as to be capable of rapid and subtle temporal coding, and so as not to interfere with subsequent stimuli), and was not objectionable. The typical description of the sensory results of electrically stimulating hairy regions, representing 90% of the "useful" body surface, had often been of a bright, stinging or burning pain. Part of our problem was to find out something about pain itself in order to be rid of it.

The first step concerned electrode size. A direct relation is found between electrode size and the likelihood of pain at a given intensity level. We use two electrodes, the "active" one much smaller than the indifferent; stimulation is thus restricted to the smaller electrode due both to its greater current density and to the relative insensitivity of the footpad, the site chosen for the indifferent electrode. A smaller active electrode requires less total power. However, increasing the size of the electrode increases the ratio between touch and pain thresholds. An electrode no larger than a dime is satisfactory on hairless tissues

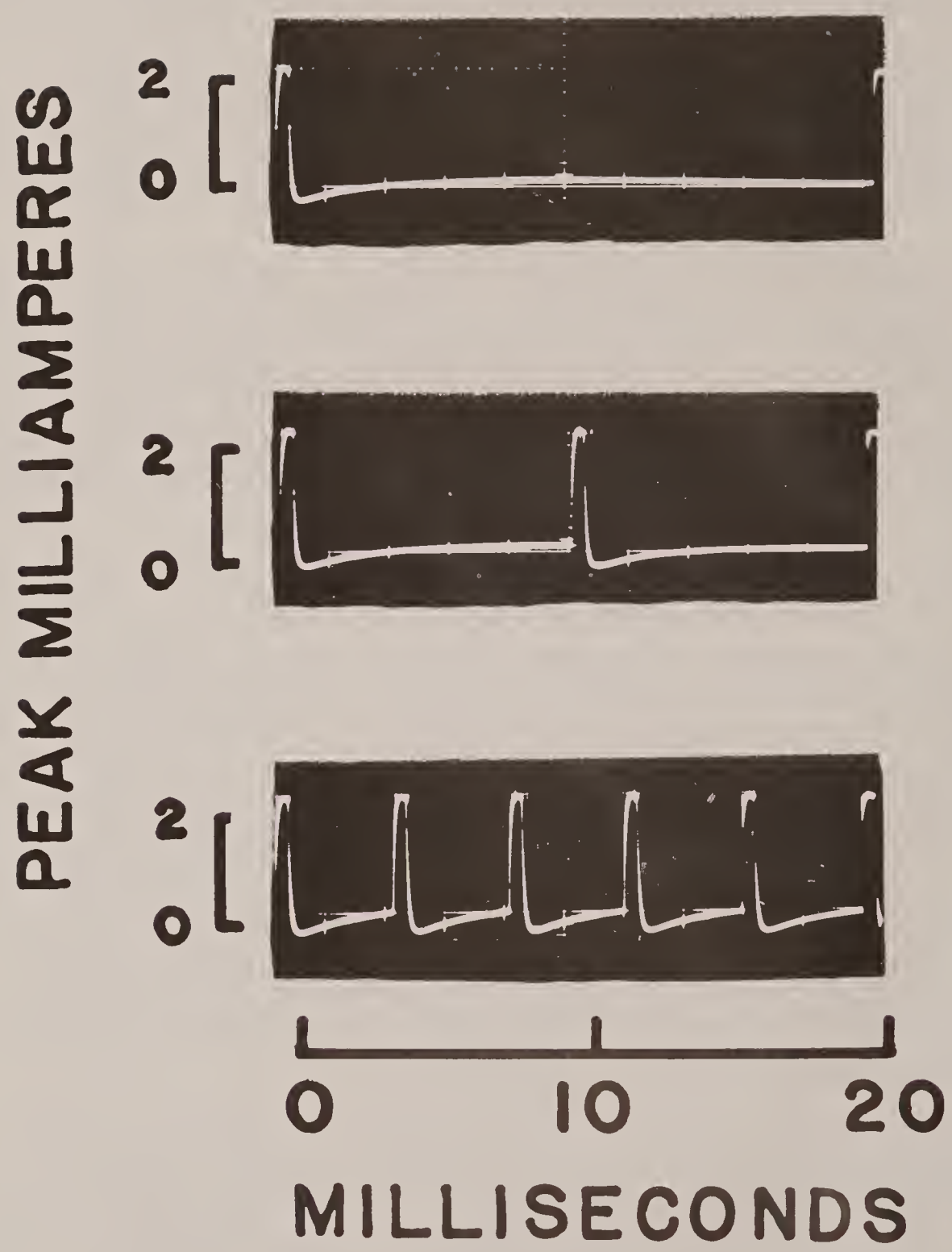

Fig. 1. Representative stimuli of 20 msec. duration, composed of different numbers of brief pulses of current. Actual photographs are from the face of an oscilloscope connected across a resistor in series with the observer's tissue. The bottom photograph shows 6 pulses of approximately 0.5 msec. duration, each separated from the next by 4 msec., a pulse repetition rate of 250 pps.

(which, in general, are well innervated); a larger electrode, e.g., quarter-sized is necessary for some hairy tissues. Regions of high neural density require only small electrode areas for a given pain/touch threshold ratio.

Next was the question of stimulus polarity. Negative pulses require roughly 60 - 70% of the power required to stimulate touch with anodal pulses. However, the ratio between pain and touch thresholds decreases percentagewise with cathodal stimulation. With respect to the mechanism underlying electrical stimulation of pain, this suggests a possible chemical basis for stinging pain, whereas there is good evidence that electric stimulation of touch represents direct neural stimulation. Positive pulses were used in the present experiments since they increase the ratio between touch and pain and provide more reliability for pain thresholds. Furthermore, using anodal stimulation, a greater number of intense stimuli can be applied to the skin over a given long period before the pain threshold is lowered.

Using positive pulses, and moderate-sized electrodes, four subjects were carefully chosen and subsequently well trained. After one month's training these subjects could report pain thresholds matter-of-factly with no emotional reaction. This was desirable. In one sense, this represents a functional separation of pain reaction from actual pain sensation, in Beecher's terms.[1] It became clear during preliminary stages that pain thresholds could be raised relative to touch thresholds and stabilized in selected subjects, and that pain threshold judgments could be rendered reliable with the appropriate stimulus control and careful training.

The technique with these subjects was to increase peak current for a given stimulus by small steps up to pain threshold. If touch was reported before pain, the intensity was increased in steps until the subject first reported pain. Thus the subjects in effect controlled the stimulus application. Apparently a psychological advantage was provided which helped stabilize pain thresholds.

Using this graduated current technique, temporal characteristics of the stimulus were manipulated. Stimulus applications were spaced in time by 15 seconds, and as current was increased the subject reported either pain, or first touch and then pain. All pulses were approximately 1/2 millisecond in duration. Before deciding on these particular figures, both pulse width and interpulse interval were systematically varied at low repetition rates to determine the pulse width that would provide the greatest ratio between pain and touch thresholds. Long pulses, i.e., 20 - 50 msec., elicit pain responses on hairy tissues, and may sensitize the area so that it cannot be stimulated painlessly again for some time, even at lower current levels. On the other hand, very short pulses, 1/10 millisecond or less, require a very high peak current to stimulate touch, thus developing large peak voltages across the skin which apparently exceed the dielectric breakdown voltage of the skin and thus stimulate pain. Increasing the duration to about 0.5 millisecond lowers the peak current requirement considerably. The value for touch chronaxie is such that increasing the pulse duration beyond 1/2 millisecond does not significantly lower the touch threshold, and pain threshold on most tissues <u>is</u> lowered when pulse durations are increased beyond this point. Thus, a pulse duration of about 0.5 msec. represents a useful compromise.

The first experiment involved a formal manipulation of the number of pulses at one rate of pulse repetition. The stimuli were applied through electrodes on each of eight locations on each observer's body. The interval between applications of the stimulus was 15 to 20 seconds. Current was gradually increased until the subject reported pain, after which that spot was retired for 2 or 3 minutes rest. Both the interstimulus time and the recuperation time are important variables and were established empirically to maximize pain threshold stability.

The graphs in Fig. 2 show mean pain and touch thresholds as peak milliamperes plotted against the number of pulses per stimulus application, from 1 to 20 pulses with a constant repetition rate of 100/sec. Thresholds were obtained on both hairy and hairless tissues. Pain thresholds on both hairy and hairless tissues decrease in a negatively accelerating manner as the number of pulses is increased. Touch thresholds also respond by shifting when pulses are added to the stimulus, but the threshold shift is much less impressive than with pain thresholds. The shift with additional pulses is less on hairless than on hairy tissues. Thus, were one selecting a stimulus largely on the basis of a maximum ratio between pain and touch, a likely candidate would be a one-or two-pulse touch stimulus applied to hairless tissues, since the pain/touch current ratio is greater. An additional advantage is that less current is required for a touch of a given subjective intensity on hairless than on hairy tissues.

In experiment II frequency or repetition rate was varied. The question was, To what extent does the time between pulses distinguish between the pain and touch systems? Stimuli of four pulses and 20 pulses were presented at repetition rates of 10 to 250 cycles per second. This is the range of best sensitivity of the skin to mechanical vibration both absolutely and as regards repetition rate changes, and probably the range that will be useful for coding.

In Fig. 3, as in Fig. 2, the two graphs represent hairy and hairless tissue, since the pain is perceptually "different," and I suspect there may be different mechanisms responsible for the pain that limits stimulation in the two types of tissue. Also, touch stimulation on hairless tissue requires only about half as much current as on hairy tissue. The pain thresholds are uniformly above touch threshold and fall with repetition rate, with the exception of one point. At low repetition rates, pain thresholds are quite high. The threshold reaches its low in the middle range, around 100 pulses per second, and then apparently rises again around 250 pulses per second with stimuli of 4 pulses. (This rise probably reflects decreased total duration rather than repetition rate per se.) Touch threshold is much less influenced by varying repetition rate. Relatively constant touch sensitivity over a broad range of repetition rate would be of advantage in a communications system since only minor current variation would be required in order to maintain constant subjective intensity while varying repetition rate (or number of pulses). Note also that the pain threshold still varies with the number of pulses in the stimulus. The 4-pulse stimulus yields a higher threshold than the 20-pulse stimulus, both absolutely and relative to touch; the influence of pulse number depends partly on the rate of pulse repetition, being relatively less at middle frequencies than at low frequencies.

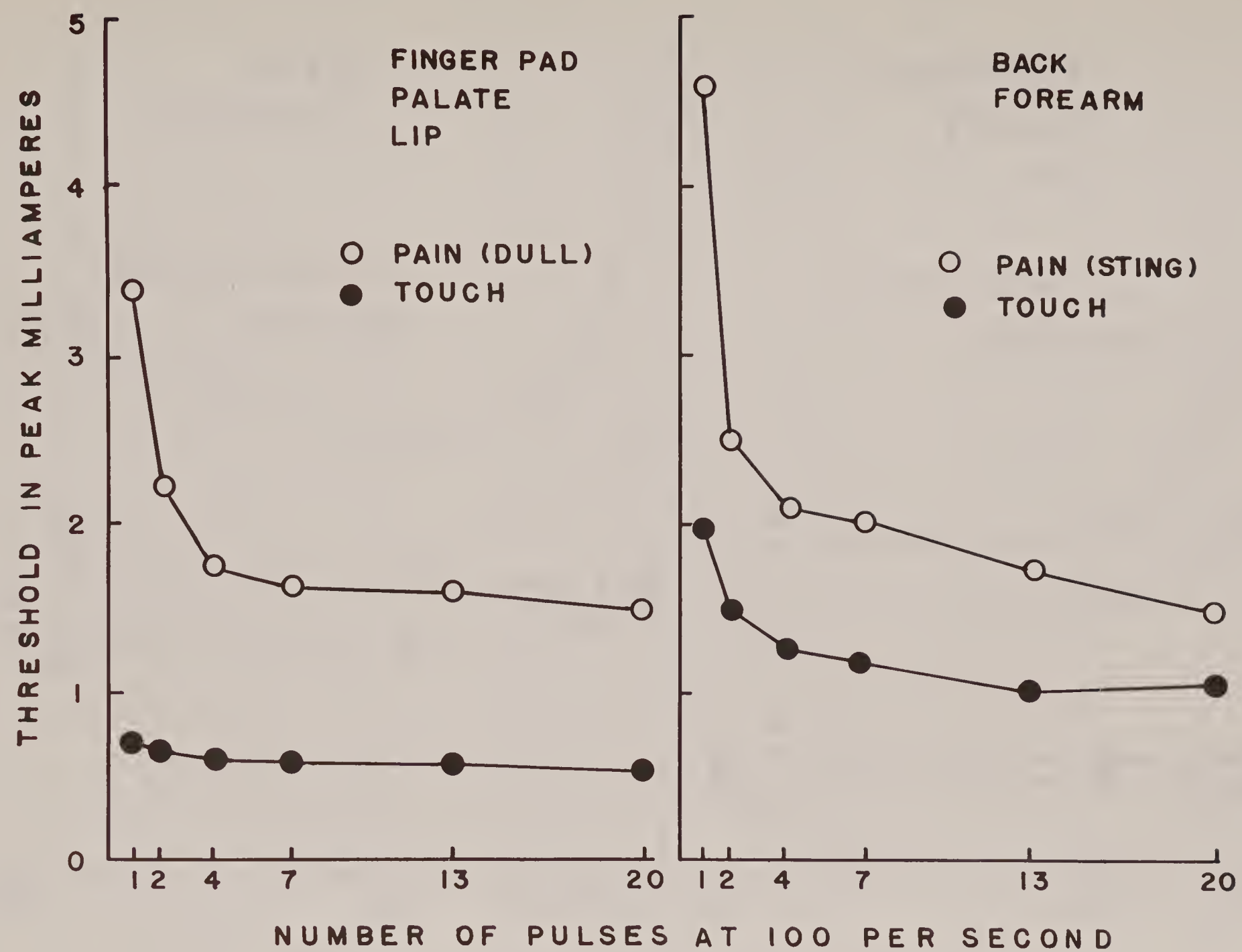

Fig. 2. Pain and touch thresholds in peak milliamperes, on various body sites, as a function of pulse number rate. Body regions are separated on the two graphs according to anatomical differences: hairless, high neural density, and hairy, low neural density. This classification closely corresponds to differences in the nature of electrically stimulated pain on those tissues.

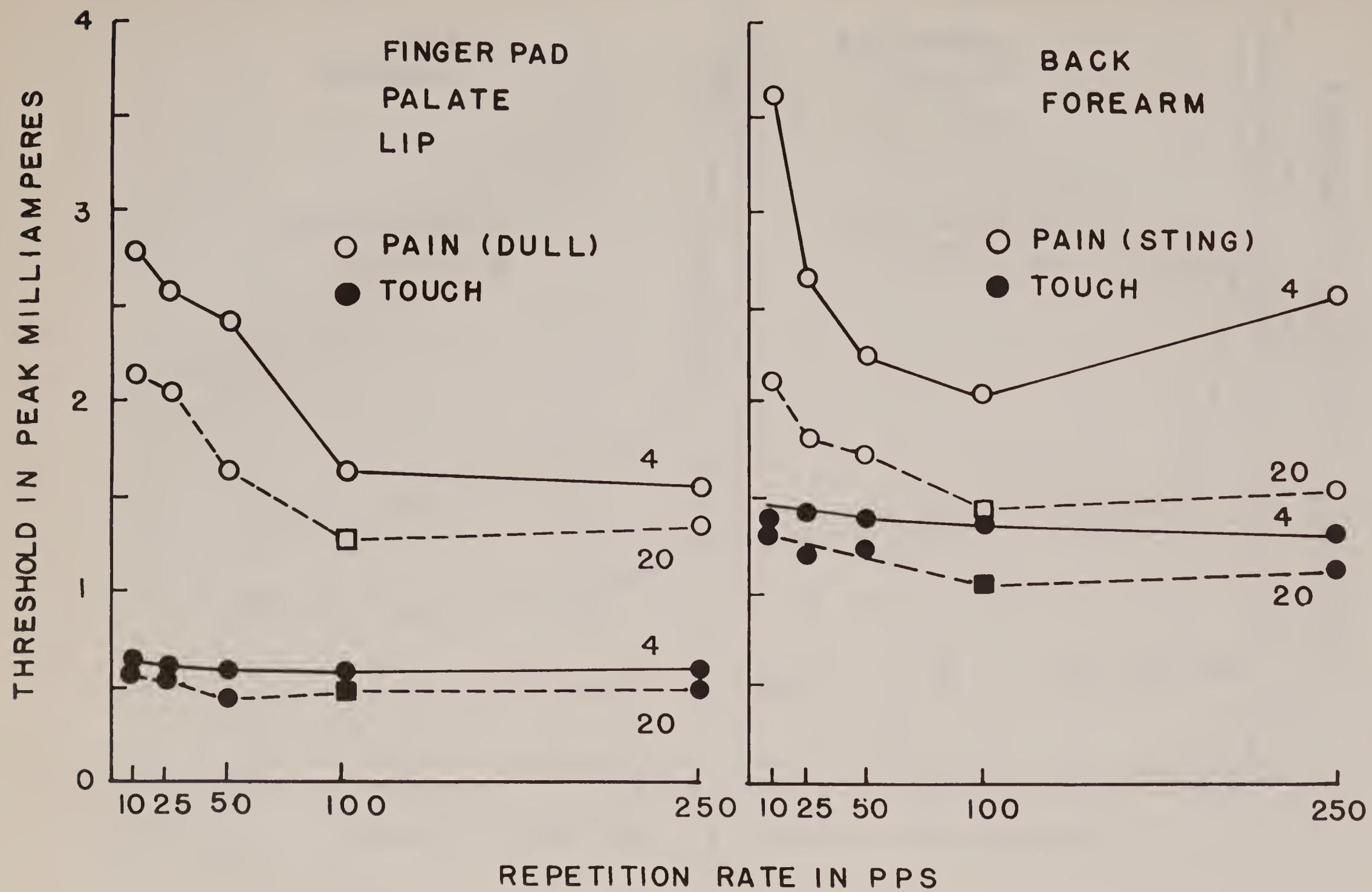

Fig. 3. Pain and touch thresholds in peak milliamperes, on various body sites, as a function of pulse repetition rate. Body regions are separated on the two graphs according to anatomical differences: hairless, high neural density, and hairy, low neural density. This classification closely corresponds to differences in the nature of electrically stimulated pain on those tissues.

Selecting a stimulus then for reliably pain-free electric stimulation of touch, paying heed to the ratio between pain and threshold currents, it would be advisable to: (1) use an active electrode of an inert metal that is not too small, perhaps 8 mm diameter for hairless tissues and 15 - 30 mm diameter for hairy tissues, (2) lead anodal pulses from a constant current device through the electrodes with pulse durations of about 0.5 msec., (3) if desirable combine the pulses into packages of probably 4 pulses or less, although the number used for a given pain/touch threshold ratio depends partly on (4) the rate of pulse repetition, which needs to be low, 10-30 pps.

Reliably pain-free electrical stimulation of touch can be accomplished with such stimuli over much of the hairy surface of the body, a distinct advantage for several categories of coding endeavors. As part of our own program using such stimuli we have stimulated clear "touch" on hairy tissues well over 10,000 times using varied patterns of electric pulses. Less than three dozen transient, trivial "stings" have been reported. Most of these came from the first few stimuli at the start of the sessions.

One final comment is in order about differences among bodily locations. What anatomical features relate to the pain-free nature of electrically stimulated touch on the fingerpad: The horny covering? Perspiration ducts that might provide preferential passage of electricity by bypassing certain receptors? The lack of small unmyelinated nerve fibers related to stimulation at least of pain? The high density of its touch innervation? The hard palate, which has a low electrical touch threshold relative to its pain threshold, is not equipped with a thick layer of horny protective tissue and lacks perspiration ducts. Thus these factors do not explain differences between threshold pain and touch as to their response to temporal factors in the electrical stimulus. One easily and precisely localizes a crumb or a bit of potato chip stuck to the palate. This suggests that like the fingerpad, this region is nicely supplied with touch neural equipment. Finally, like the fingerpad, the palate also lacks small nerve fibers. These are desirable features in the present context: high touch sensitivity coupled with low pain sensitivity.

Less current was required to stimulate touch on the palate than was needed on the seven other body regions used in the present experiments. Touch stimulation was pain-free for large relative excursions of current above touch thresholds. Individual threshold current differences were somewhat large, but variations within an individual were small. Thus once an observer was trained to accept an electrode into his mouth, touch threshold was reasonably invariant across a variety of different stimulus combinations. The immediate thought is of a prosthetic device designed to take advantage of the keen localization coupled with the relative freedom from pain. A device attached to the molars could be insulated with epoxy and arranged to spring some electrodes up against the hard palate. The sensation through such an electrode is described as a dull thud, felt subjectively 1/16" within the skin. It is not at all unpleasant, once familiar.

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SOME ASPECTS OF TACTILE-KINESTHETIC CODING*

by

Dr. James C. Bliss**

I INTRODUCTION

The kinesthetic and tactual senses, probably the most indispensable of our sensory systems, offer many possibilities for increasing the methods of conveying information to a person. These senses respond to a wide range of variously constituted stimuli, which may be mechanical, thermal, electrical, or chemical. Type of stimulation, location, intensity, and time can all be used as information-bearing elements. Moreover, the information can be acquired by the active or passive participation of the observer. For example, when information is handwritten on the skin of a blind-deaf person, he is a passive receiver, whereas in reading braille he receives information by the active movements of his fingers across the embossed dots.

Also, it is likely that the tactual sense may contribute more heavily to the general activation level of the organism than the visual sense. Several investigators have found differences between sensory modes with respect to their ability to arouse cortical activity, nociception and proprioception offering the greatest contribution, audition and vision the least.

Machine aids for tactile communications have been developed by several investigators. However, even though the kinesthetic sense is a major information channel for the blind in both reading and mobility, few, if any, attempts have been made to utilize this sense directly in a mechanical display. A display designed primarily to stimulate the kinesthetic sensory channel will be described in this paper.

First, two general system models will be proposed, and then realizations of these systems will be discussed.

II SYSTEM CONSIDERATIONS

In order to discuss various problems concerning information transmission via the kinesthetic and tactual senses, we will first postulate a general system model for a machine communication aid. This model is shown in Fig. 1. The block labeled "source" represents any place from which information is to be obtained, such as the visual world, sound, or a book. The role of the "sensor" is to acquire information from the source and transduce it into a form suitable for processing. The "processor" may perform some of the following functions: storage, information filtering, recognition, and encoding. The processed information is transmitted to the "display" block, representing the method by which information is presented to the human.

The human is divided into two blocks in the model of Fig. 1, "sensory channels" and "user." The "sensory channels" block represents the sensory transformations which take place in the nervous system. The block labeled "user" represents a human who is trying to obtain information of interest to him from the source.

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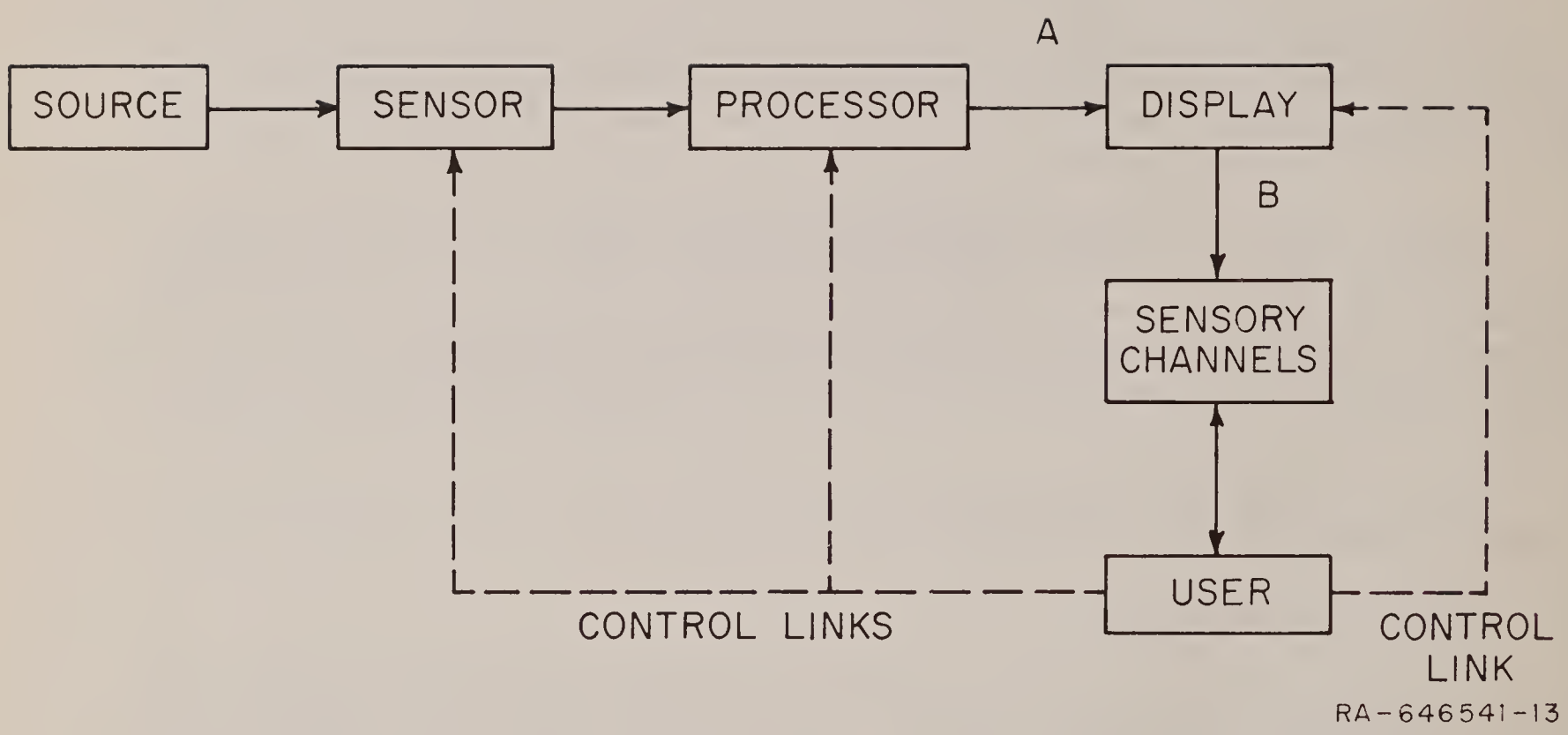

Fig. 1 A System Model for a Machine Communication Aid

An important aspect of this model is the control which the user may exert over the system. By way of the control links from the user to the sensor, processor, and display, information can flow from the user to the system, so that the system can adapt itself or be programmed to satisfy the desires of the user. The importance of this control in learning to receive a high rate of information through complex atypical stimulation is implied by the experiments of Held.[1] He has shown that compensation for various optically produced rearrangements requires stimulation that changes as a consequence of the movements of the observer.

There is psychological evidence which indicates that complex stimuli are needed to obtain a high information rate. For example, the experiments of Erikson[2] imply that the rate at which man can receive information increases with the dimensionality of the observations, even though the differences in physical dimensions between stimuli are perfectly correlated with one another. Furthermore, Sumby and Pollack[3] have shown that the rate of continuous information transmission increases with the number of message alternatives.

Based on such psychological evidence two hypothetical methods of interest for obtaining high information rates are methods in which the system recodes the source information into "equal information units" and methods in which the user recodes the source information into "equal information units" via the display and control links. Both of these systems attempt to convert a source which generates information at a non-uniform rate into a constant-information rate system.

The method in which the system encodes the source information into "equal information units" is based on an analogy with language units which closely resemble perceptual units, such as stenography, Grade II braille, Japanese kana, and morphemes. These language forms have a more uniform information distribution among their basic units than the English alphabet. For example, Grade II braille contains 180 contractions of the more frequent words and letter combinations in English, so that in the transformation from English letters to braille cells there is a marked increase in the uniformity of the distribution of information per symbol. Thus the information is in approximately equal information units at Point A in the model of Fig. 1.

However, this method has a disadvantage which could possibly limit its information rate, especially if the system is in widespread usage. Information units which are psychologically equal depend on the user's expectations or uncertainties, not on the true probability distributions. The user's expectations are certainly not constant in time or among different people. Therefore, unless the encoder has the ability to determine the user's expectations and then modify the code in an understandable fashion, it can at best only approximate a constant information rate. For example, Grade II braille only approximates a constant amount of information per cell in the interest of having a standard code with some degree of permanence.

The second hypothetical method for obtaining a high information rate is analogous to visual reading. When a person reads, his eyes move in saccadic jumps to various fixation points. The length of these jumps and the time spent at each fixation point varies from jump to jump.

Cherry[4] suggests that, in reading, the length of these saccadic jumps and the fixation times may be related to the psychological information content of the test. It may be that one purpose of these saccadic eye movements is to group the printed letters and words into more or less equal information blocks. In this way, a fairly constant rate of perceptual information intake is obtained, even though individual letters and words vary greatly in the information they carry. In fact, the reason written language evolved into a form in which equal lengths of symbols do not carry equal information may be because the spatial aspect of vision is suited to grouping information into equal units, thus permitting the length of a sequence of symbols to be another stimulus dimension for coding.

For this method in which equal information coding is done by the user, the information is displayed in such a way that the user can easily group and arrange the information to obtain a fairly constant rate of perceptual information intake. Thus, at Point B in the model of Fig. 1, the information is in approximately equal units. The advantage of this method over the method in which the encoding is done automatically is that the psychological expectations are used in the encoding.

III A KINESTHETIC-TACTILE COMMUNICATION SYSTEM

The kinesthetic-tactile display to be described here was designed to be primarily germane to the problem of transmitting English text. The input to this display in a practical application could be the output of a character reading machine, a teletypesetter tape, or an electric typewriter. In this research study, however, punched paper tape was used as the information carrying medium.

Since the fingers have many degrees of freedom, are heavily innervated, and have a large representation in the cortex, passive movement of the fingers was chosen as an information-carrying stimulus in this display. These movements are obtained from a set of eight finger rests which can be automatically positioned in three-dimensional space according to a prearranged program.

The display is powered by compressed air, and a pneumatic paper-tape reader is used to valve the air pressure to specific brass Sylphon bellows. These bellows, in turn, move the finger rests. Fig. 2 shows the basic system used for each finger rest. Each bellows assembly gives plus and minus colinear movement and the three bellows assemblies have mutually perpendicular axes. With this basic unit, $3^3 = 27$ positions of the finger rest are possible.

The complete system with eight finger rests is shown in Fig. 3. This display has $3^{24} = 2.8 \times 10^{11}$ possible states, which give considerable flexibility for experimentation with complex stimuli. An attempt was made to enhance the tactile cues from the relative motion between the fingers and the finger rests by making half of each finger rest have a different texture.

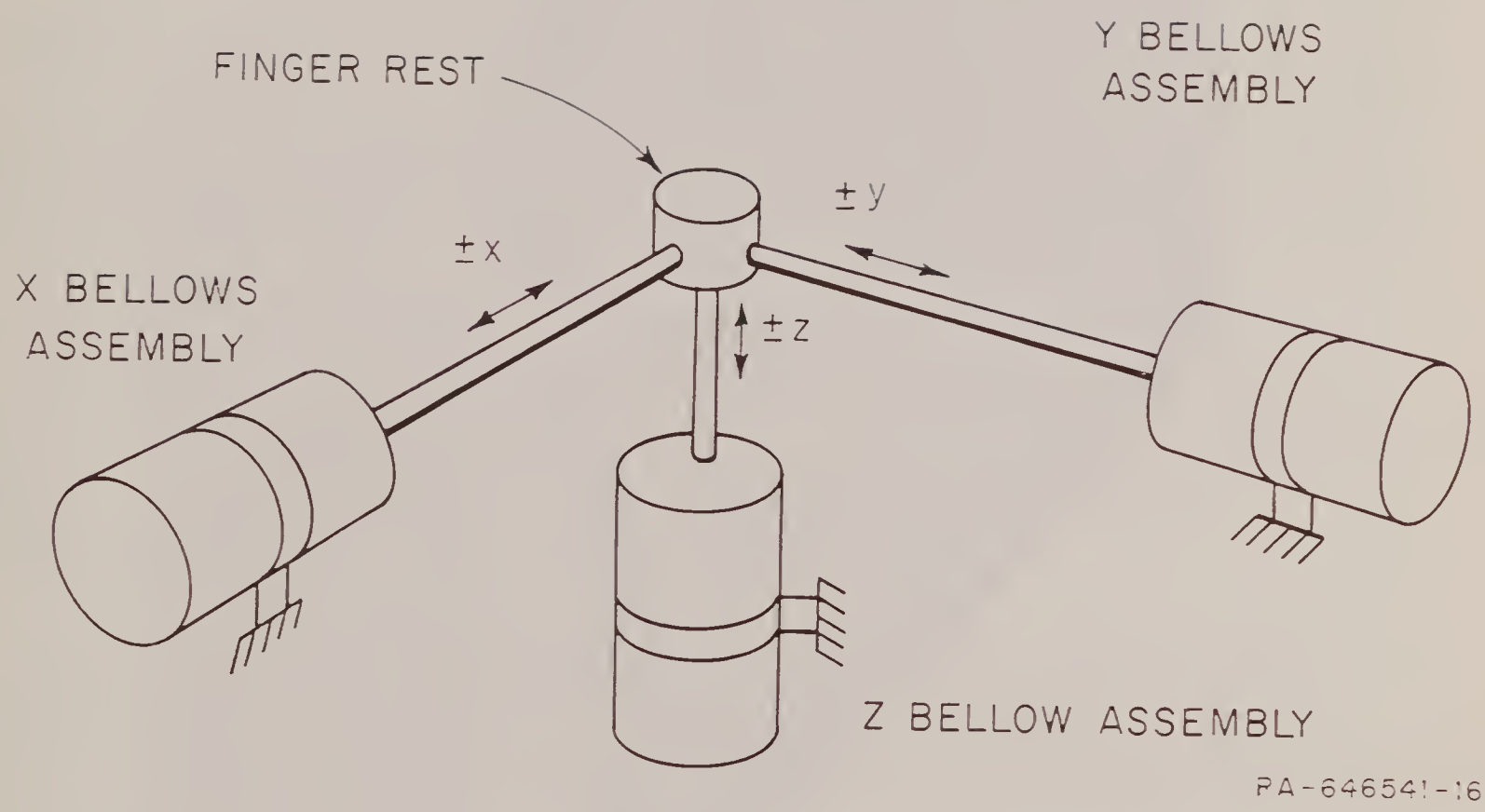

Fig. 2 Schematic Diagram of a Single Finger Stimulator

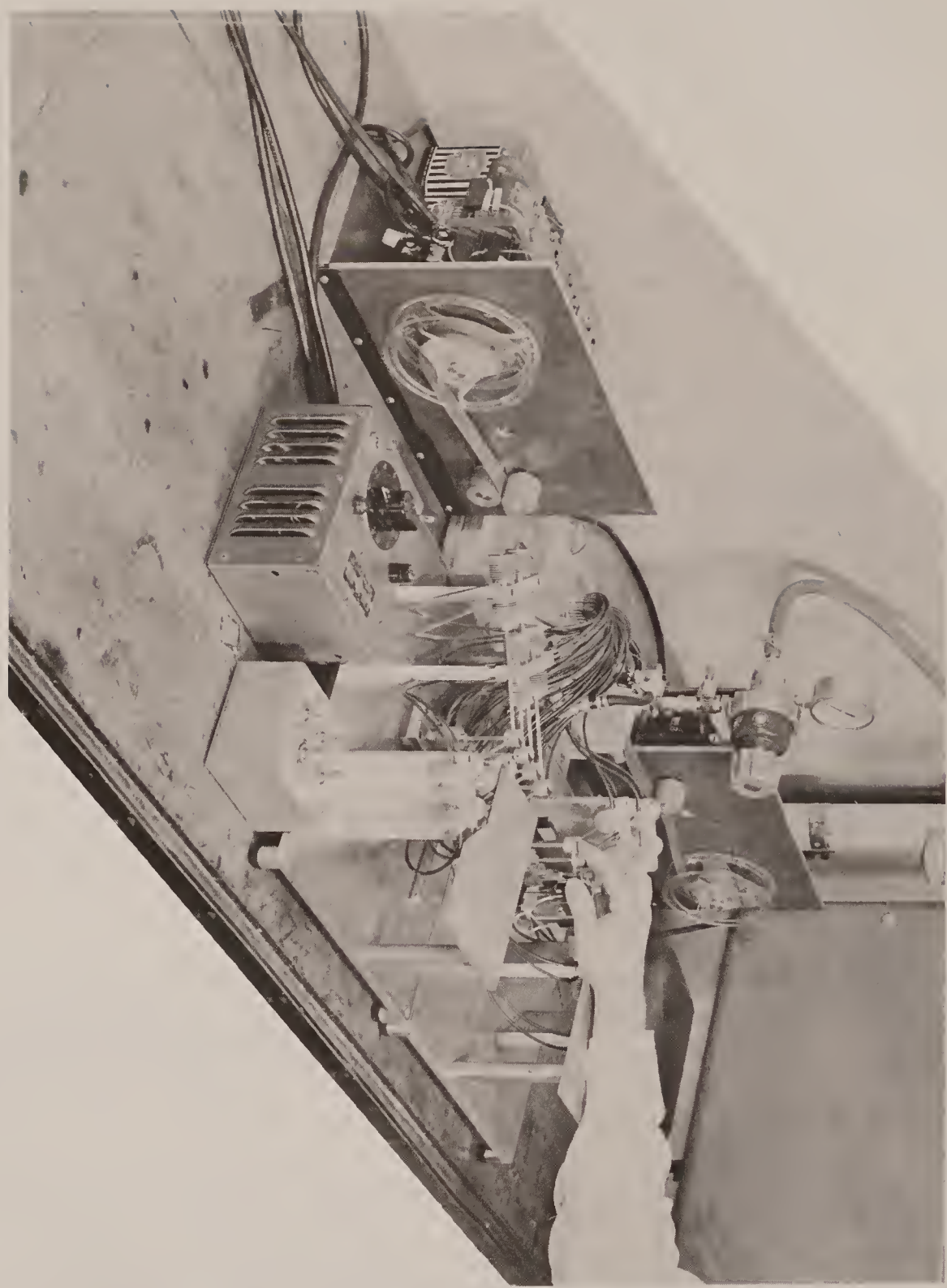

Figure 3.

Moreover, an edge separates each finger rest half so that a tactile reference direction is given to aid the user in orientation.

There are many ways in which the pneumatic paper-tape reader can be used to program information presentations on the finger stimulator. Since each finger rest can be in any one of 27 stimulus states at each instant of time, any possible presentation can be described in terms of a location-time-stimulus coordinate system. The essential difference between the various presentations is the way in which the location aspect of the kinesthetic sense is utilized. In one presentation (traveling-wave), the location of the stimulus is merely used as an aid to memory; that is, the information is repeated at different locations, but the temporal order in which the locations are stimulated indicates the sequential order of the information. In another presentation (typewriter), location is used directly as an information-carrying dimension. We shall discuss only the traveling-wave and typewriter presentations.

IV THE TRAVELING-WAVE PRESENTATION

In this presentation, each movement is repeated in sequence at all of the finger rests. Thus a three-dimensional traveling-wave moves across the display. This display method is analogous to the way news is presented in Times Square, New York City.

The advantage of the traveling-wave presentation is that it attempts to use the location aspect of the kinesthetic-tactual senses to allow the user to approximate the spatial aspect of vision. In this presentation, the user can "see" more than one letter at a time. He can attempt to fixate at one finger location, yet have some "peripheral" indication of letters ahead and behind the "fixation" point. In this way, it might be possible for a subject to learn to read "words" instead of "letters."

A code for mapping the letters of the alphabet, numbers, and symbols into a traveling-wave presentation has been written. Only six directions of movement are used in this code. Two successive movements of one finger are used to represent an alphanumeral, so there are 36 distinguishable pairs of movements and 6 distinguishable single movements, giving a total of 42 possible stimuli.

Several experiments were performed with the traveling-wave presentation. In the first experiment, two subjects learned the code for the six letters e, t, o, a, n, i and an attempt was made to see if they could learn to recognize "words" composed of these letters. Tapes were prepared with words in random order from a list of about 60 words containing only these six letters. Fig. 4 shows the learning curves obtained from this experiment. Only one hand was used for these trials.

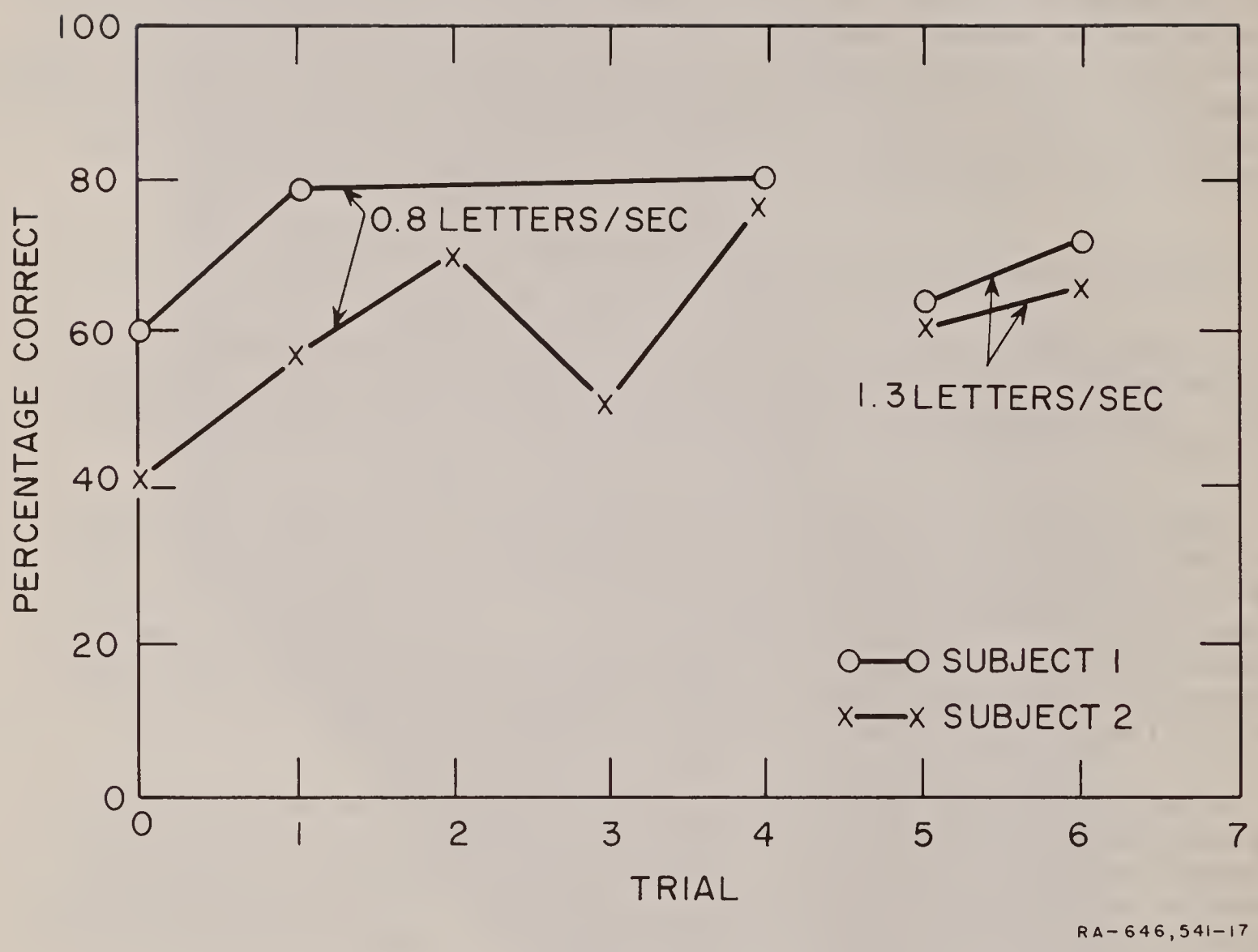

Fig. 4 Learning Curves for the Traveling-Wave Display

It was felt by the subjects in this experiment that the repetition and the presentation of more than one letter at a time caused confusion. It seemed by introspection that the presentation of two letters simultaneously resulted in a sensation that was not easily recognized as the sum of the sensations received when each letter was presented alone.

In another experiment with the traveling-wave presentation, 42 random triplets composed of the letters e, t, o, a, n, and i were presented to eight subjects, using a single hand in each case. A multivariate information analysis of the responses was made in order to separate the effects of letter position in the triplet, individual differences, and movement directions. The speed was held constant at 2 letters/sec.

Fig. 5 gives the results of this experiment in terms of these measures. An information rate of 2.58 bits/letter was the maximum possible in this experiment. Also, the letter spacing was such that the second letter of the triplet never occurred alone, while the first and third letters occurred alone twice. Therefore, it is interesting to note that the average transmitted information for letter position 2 was only about 70% of the transmitted information for letter position 1 or letter position 3. This result implies that when two letters are presented at once, the information rate per letter is significantly reduced.

V THE TYPEWRITER PRESENTATION

In the typewriter presentation, the subject's fingers are moved corresponding to the way he would actively move them if he were typing. That is, finger movements in the vertical direction indicate the "home" keys (a, s, d, f, j, k, l); finger movements away from the body indicate the characters corresponding to the third row on a typewriter; and movements toward the body indicate the bottom row characters on a typewriter. In addition, the following modifications are used:

1. The "home" characters are indicated as follows: a-down, s-up, d-down, f-up, j-down, k-up, l-down. (Since more errors in localization result from confusion between adjacent fingers, this arrangement was chosen to make adjacent characters differ more.)

2. The space bar is indicated by a simultaneous movement in the x direction of the middle fingers on both hands.

3. The numbers, which are on the fourth row of a typewriter, are indicated by a simultaneous movement of the little finger on the hand opposite to that corresponding to the number being sent.

4. Lower case and upper case are indicated by the simultaneous movement of <u>three</u> fingers.

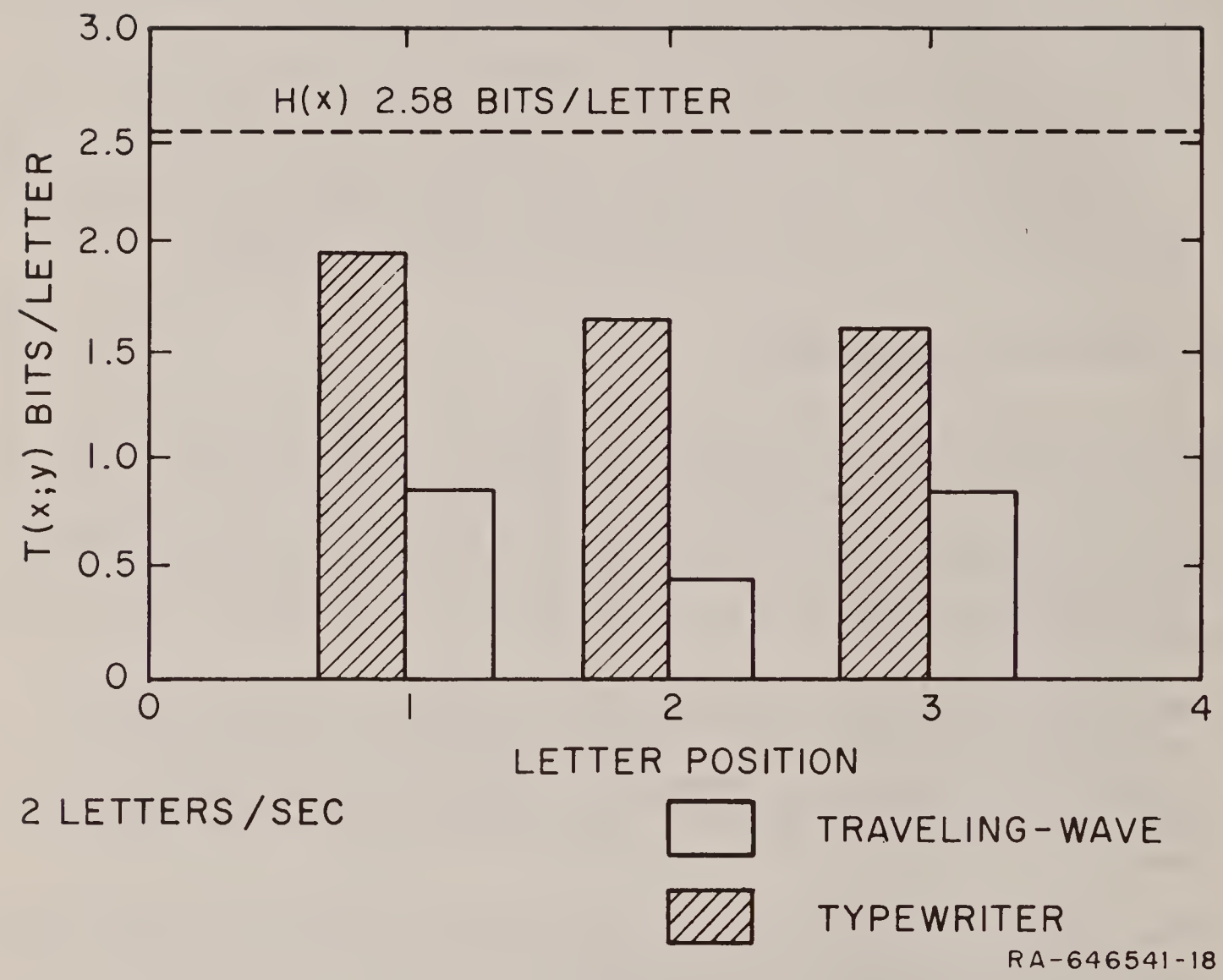

Fig. 5 Comparison Between Performance Obtained with the Traveling-Wave and Typewriter Displays

While this presentation has the advantage over the traveling-wave presentation of using the location aspect of the kinesthetic-tactual senses more effectively, it also has the disadvantage of presenting only one letter at a time.

Three experiments were performed with the typewriter presentation. In one phase of experimentation, a blind subject spent approximately two hours a week for two months practicing with this display. This training period is described below.

In the first practice period, the subject became familiar with the machine and the stimuli for the letters, numbers, and symbols. Since she already knew how to type, the amount of learning required was slight. In the second practice period, a list of the most frequently used English words was presented, and by the end of the hour, these could all be recognized correctly at a rate of about 5 words/min. In the succeeding periods, the subject practiced with material from a fourth grade reader and the Reader's Digest. After about six one-hour sessions, the subject was reading this material at a rate of approximately 10 words/min.

At this point, some improvements were made on the system. Wind and rewind tape reels were added to the punched paper-tape reader with controls that can be operated by the subject. These controls consist of micro-switches so placed that the subject can operate them with his thumbs. Pressing with the right thumb stops the display, and pressing with both thumbs reverses the tape. In this way, if a letter or word is missed, it can be repeated. Also, the start/stop switch controlled with the right thumb serves as a rudimentary speed control.

With the addition of these controls, there was an almost immediate increase in word rate to about 15 words/min. However, due to the way this presentation was programmed, the air pressure was on only about 1/8 of the time. This resulted in a decrease in the amplitude of motion at speeds greater than 15 words/min.; therefore, this reading rate was probably a machine limitation, not a subject limitation.

In the second experiment, the 42 random triplets used in the traveling wave experiment described above were presented to eight subjects in order to obtain an objective comparison between the traveling-wave and typewriter presentations. Fig. 5 compares the results of the two experiments on an information transmitted basis. The average transmitted information was 1.75 bits/letter for the typewriter presentation and 0.73 bits/letter for the traveling wave presentation out of a maximum possible 2.58 bits/letter.

In the third experiment, 30 symbols (the alphabet, comma, period, space, and upper case) in Typewriter Code were presented in random order to one subject. Sequences of these symbols were generated with the aid of a random number table so that all symbols were equally probable. Therefore, the self information of each symbol was 4.91 bits. The experimental stimuli consisted of six sequences of 130 symbols each, and the presentation rate of each sequence was chosen to cover the range from 0.5 to 1.5 letters/sec. The subject responded orally by naming the symbols as they were received.

Fig. 6 shows the results of this experiment. The information in the correct responses was calculated by means of the following formulas:

$$T = \frac{\%\ \text{correct}}{100} \times 4.91 \quad \text{bits/symbol}$$

$$T = \frac{\%\ \text{correct}}{100} \times 4.91 \times \text{Presentation Rate bits/sec.}$$

The maximum information rate obtained was 4.5 bits/sec., which occurred at a presentation rate of 1.32 letters/sec. However, this rate is probably not the maximum attainable for the following reasons:

1. More practice would probably increase the information rate. (The subject for this experiment had less than 15 hours of practice.)

2. The symbols in Typewriter Code are not optimally distributed among the fingers--six symbols are assigned to the index finger on each hand, while only three symbols are assigned to each of the other fingers. Consequently, 73% of the errors involved the 12 letters assigned to the index fingers.

3. The information rate could probably be increased if more than 30 alternatives were used.

4. The information rate could probably be increased if the subject were allowed to control the speed continuously.

5. Typewriter Code has the disadvantage of presenting only one symbol at a time, thus not allowing the subject to "see" ahead.

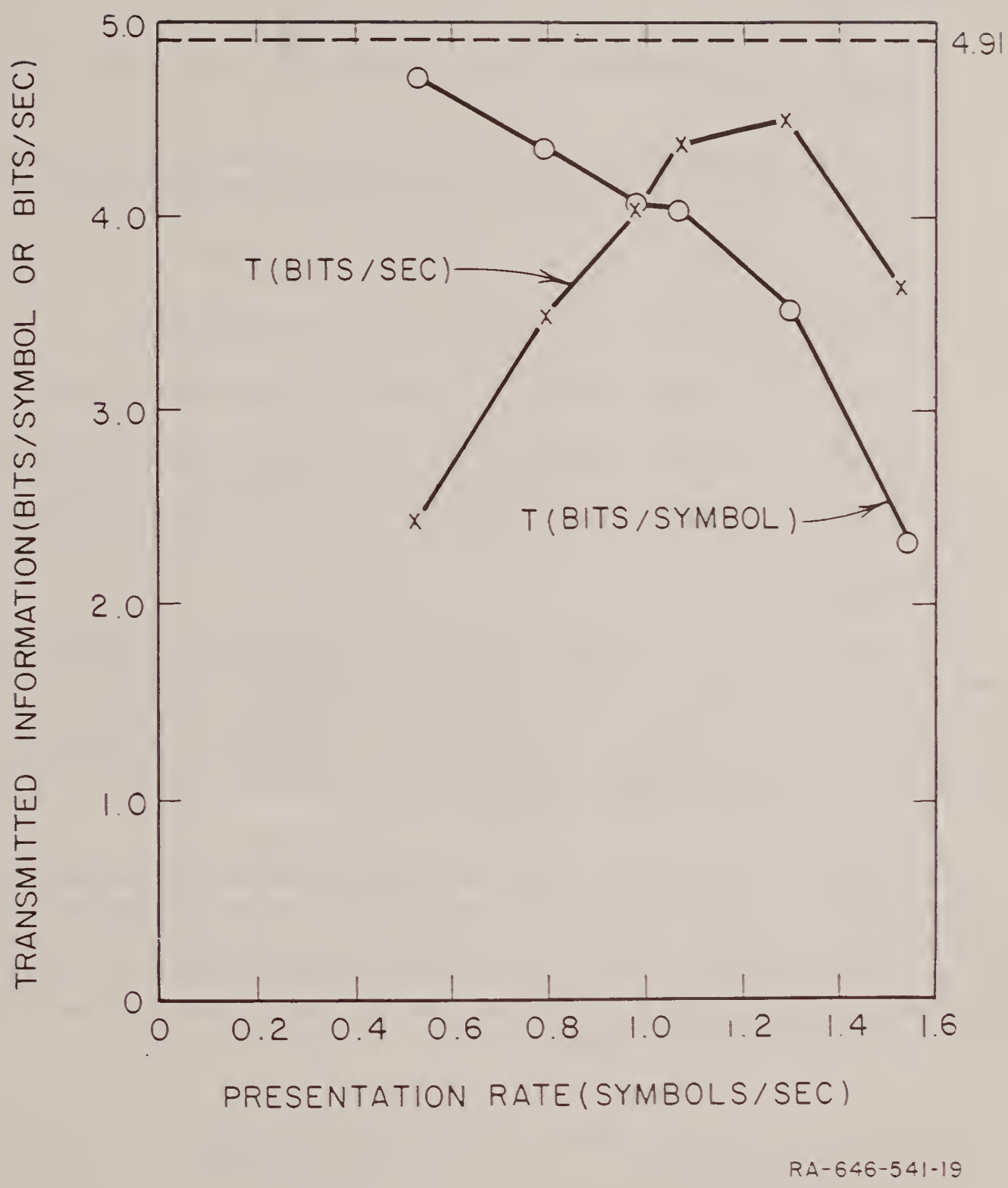

Fig. 6 Information Rates versus Presentation Rate for the Typewriter Display

VI PROPOSED TACTILE DISPLAY

Whether the second hypothetical method for obtaining a high information rate is realizable tactually depends on the extent that the skin can be used as a crude retina. In order to investigate this communication method, work is presently being done on the general system shown in Fig. 7. This system is flexible enough for a variety of significant experiments. Key features of the system are:

1. An optical transducer which produces multiple images of the visual field

2. Optical preprocessing of the visual information. The nature of this preprocessing can be easily varied for experimental purposes

3. A large number of light receptors (over 100)

4. Further electronic processing of the information

5. A tactile display which is capable of presenting patterns

6. Feedback from the subject to the optics, processor, and display.

The important parts of this system will be discussed next.

A. Tactile Display

The use of a large number of tactile stimulators presents psychological problems as well as control, power, and reliability problems. The tactual sense responds to a wide range of stimuli--mechanical, thermal, electrical, and chemical. Various types of mechanical and electrical stimulators have been used by previous investigators. Thermal and chemical stimulations appear to be too slow for a communication system.

Mechanical stimulators can be divided into the following classes: poke probe, vibrator, air jet, and texture. Poke probes have the disadvantage that the sensation rapidly damps out. Vibration does not adapt as rapidly or as much as static pressure, and the sensation from vibration is more desirable. However, the two-point limen for vibration is many times greater than the static two-point limen for a given region.

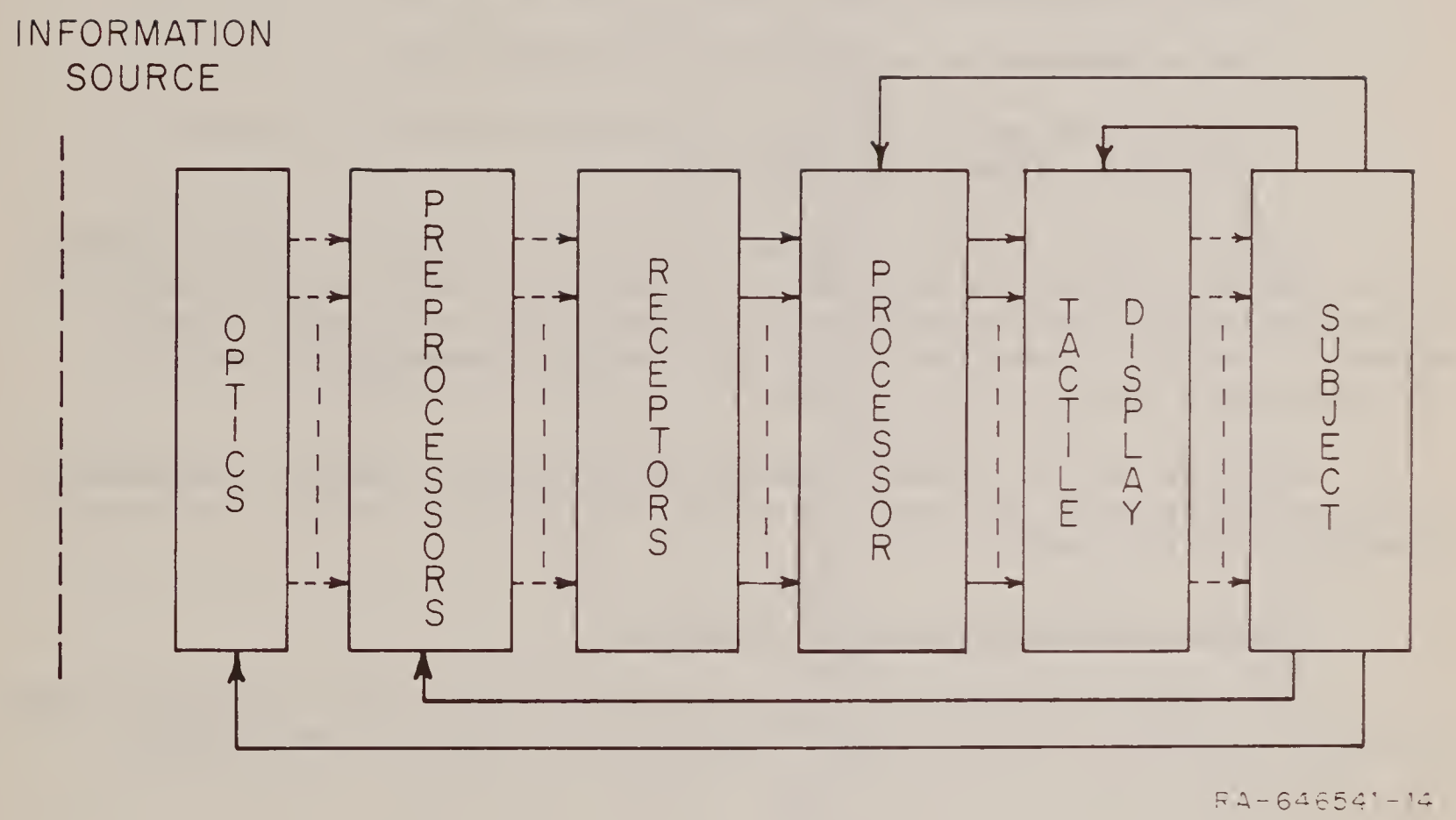

Fig. 7 System for Displaying Visual Information to the Tactual Sense

The author and Michaels[5] have investigated the possibility of using a small (about 0.020-inch diameter) moving air jet as a tactile stimulator. While an air jet is difficult to localize if it is stationary, localization is much finer if it is moving. This stimulation technique has the following advantages:

1. The sensation does not adapt out

2. The sensation is pleasant

3. Good localization is possible

4. Direct connection to the skin is not necessary

5. The stimulator is easily built and controlled

6. The air jet may be continuous or valved rapidly on and off to produce different sensations.

Figure 8 shows how a simple matrix air jet stimulator could function. In this display device, the control is performed by simple valves consisting of iron balls which can be moved away from an orifice by a small electromagnet. It has been found that the perception is enhanced if the air jet is continuously given a slight motion.

Since the use of several stimulus dimensions may improve recognition, it may be desirable to add poke, vibration, electrical, thermal, and chemical stimulators to the matrix.

B. Optics, Preprocessing, and Receptors

The optical, preprocessing, and receptor parts of the system are being developed at SRI for use as an input device for a 1000-cell Perceptron.

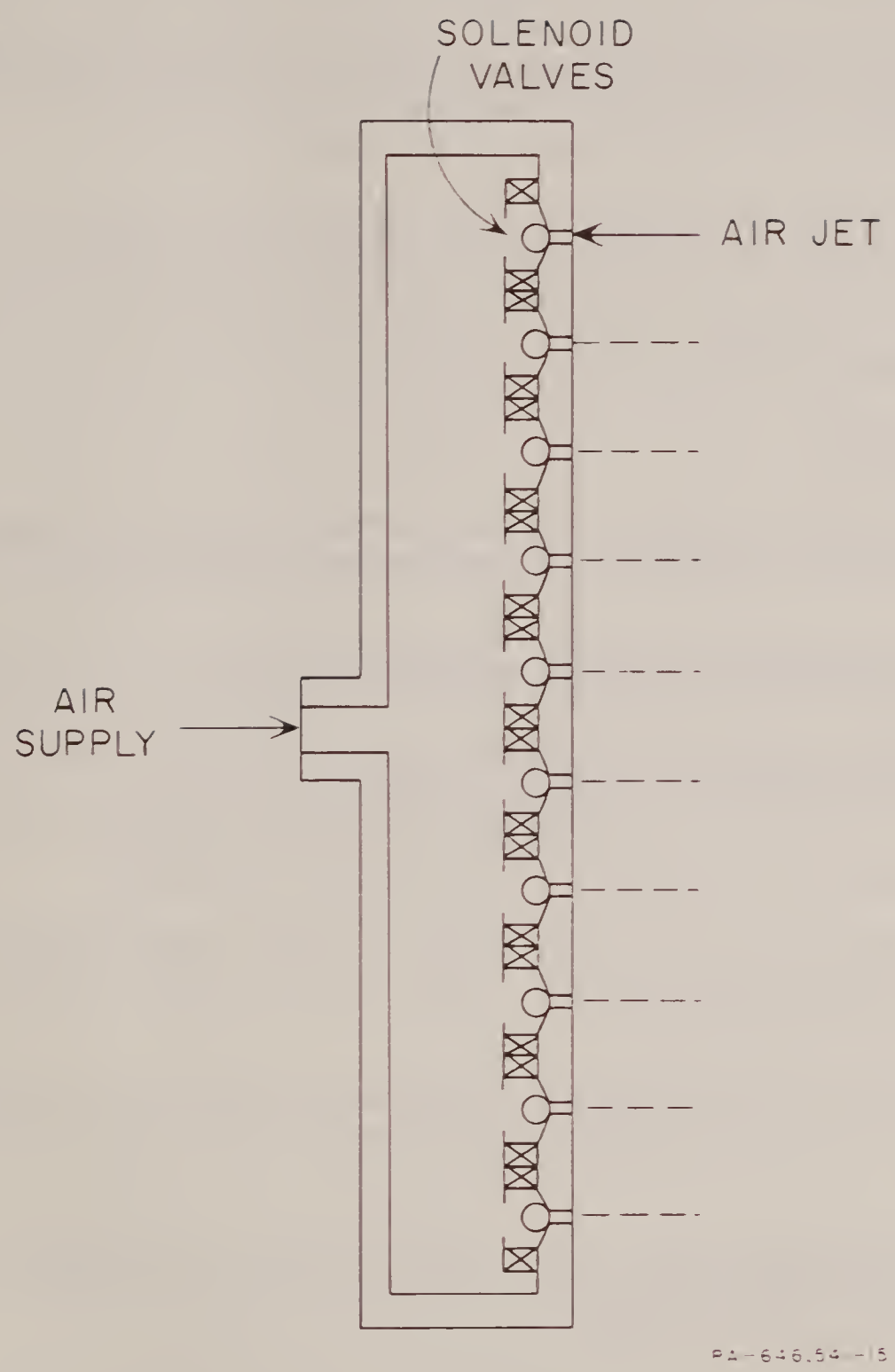

Fig. 8 Schematic Drawing of a Tactile Stimulator

C. Processor

After the information has been preprocessed and acquired, there are several operations that may have to be performed before the information can be perceived when presented to the tactual sense. For example, it has been found for the case of vibratory stimulation that two or more simultaneously acting vibrators feel no different than one, once the static pressure of each is damped out, and provided the vibratory pattern is set up in all of them with the same onset. Thus, it may be necessary to sequentially activate the tactile stimulators in some prescribed fashion.

Another type of processing that could possibly enhance tactual recognition is lateral inhibition.[6] This process, which has been found in the eye of Limulus, enhances edges, thereby emphasizing the significant portions of the visual field. Temporal lateral inhibition should also be considered for dynamic patterns.

D. Feedback Controls

The system shown in Fig. 7 allows several methods by which the subject can obtain reafferent stimulation. Some of these methods are listed below:

1. The subject may move relative to the tactile display, thereby changing the locus of the stimulators.

2. The subject may have controls on the processor, such as a scanning-speed control.

3. The subject can change the preprocessor program.

4. The subject can move the optics to allow concentration on different parts of the visual field. This could be done manually, or could be done automatically.

Many important psychological experiments could be performed with the system described above. A few examples of experiments that might be performed are described below:

1. Psychophysical Tests: Some tests on the discriminability of various stimulus dimensions will be necessary in the development of the tactile display.

2. Sensory Feedback for Prosthesis: The use of the tactile display to indicate pressure, position, temperature, and pain stimuli on an artificial limb or extension of normal limbs would be an important area of experimentation.

3. Tracking: Vibratory tracking by compensatory pursuit has been reported in the literature.[7] In the task investigated, the skin handled the assignment fully as well as the eye. With the system proposed above, much more complex tracking tasks could be presented to the subject.

4. Motion Perception: The ability of the subject to detect motion with the system may indicate useful applications as a warning device.

5. Mobility: The use of such a system as a mobility aid, both for walking and controlling a vehicle, is an important problem for investigation.

6. Manual Tasks: The amount of improvement tactual communication of the visual field gives in the performance of manual tasks, such as assembling parts, controlling equipment, etc., could be determined.

7. Pattern Recognition: To what extent patterns could be recognized tactually is an interesting basic question as well as an important practical problem.

8. Tactile Language: It would be useful to develop a language especially matched to the tactual sense.

9. Reading: Whether tactual perception of spatial patterns is precise enough to permit reading should be determined.

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SOME ASPECTS OF HUMAN VISUAL INFORMATION TRANSMISSION*

Dr. Ronald J. Massa**

ABSTRACT

This paper describes the results of a psychophysical study of visual information transmission. Both total report and sampling technques were used to investigate the span of immediate memory and short-term visual storage in connection with spacial matrix patterns. The results indicate that two characteristics of performance for short duration exposures may be predicted on the basis of whether the pattern is considered "random" or "structured" by the subjects. The results of sampling experiments intended to explore the nature of short-term visual memory for spacial patterns indicate that this memory is partially eidetic. Eye motion measurements in connection with psychophysical experiments involving short duration exposures indicate that post-exposure gross eye motion is a function of a stimulus material, and that psychophysical performance may be related to aspects of this eye motion.

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1. General

The major stimuli used in this study were patterns formed by filling in either 5 or 10 elements of a 9 x 12 matrix. Figure 1 shows 10 such patterns with 5 elements filled in. Figure 2 shows 10 patterns with 10 elements filled in. These 20 patterns, designated by the letters A through J and the numbers 1 through 10, constituted the major information source used in this investigation. The patterns subtended an angle of about 9 or 10 degrees in the horizontal direction when exposed to the subjects. This large angle, generally beyond the extent of the foveal angle of vision, constituted a major departure in this investigation from the work of others using matrix patterns of this type. [1]

The short duration exposures, described in the experiments which follow, were achieved through the use of a motion picture testing technique. By exposing the required patterns for 1,2,3,4, etc., frames of an 8 millimeter motion picture presentation, a variety of exposure times in integral multiples of 1/16th of a second with a wide variety of pre-and post-exposure fields could be achieved. The ease and facility of testing with this technique make it an attractive one for psychophysical experimentation. Figures 3 and 4 show a typical short duration exposure including the command-to-attention, fixation intervals, exposure interval, and response interval. Figure 4 depicts the light versus time characteristic attendant to a single pattern exposure.

2. Pattern Recognition and Total Report

The first experiment performed involved exposing 20 subjects to the patterns shown in Figures 1 and 2. These patterns were clearly printed on individual sheets of 8-1/2" x 11" paper and exposed to the subject all at once on a large table for as long as desired. The subjects were instructed to classify the 20 patterns into one of two groups. The two groups were called the "random" group and the "structured" group. The subjects were given no further information about the mode of classification or the basis upon which the classification was to be made. Figure 5 demonstrates the results of the "random" - "structured" grouping by the subjects. It can be seen from the results in Figure 5 that the patterns chosen vary widely with respect to "random" - "structured" grouping. Note also that there is generally greater agreement among the subjects in classifying the 10-patterns (patterns with 10 filled-in elements) into these groups. With 5-patterns it becomes difficult to make this distinction. One would expect this, since, in the extreme, it is difficult to decide if two elements are "random" or "structured".

The second experiment involved exposing 7 subjects to motion picture presentations of the 20 patterns shown in Figures 1 and 2. The durations chosen in the experimental sequence as shown in Figure 3 were 1, 2, 5, 10, 20, and 50 frames of a normal 8 millimeter motion picture presentation. The time durations of the exposures range from about 62 milliseconds to approximately 3000 milliseconds. The results are shown in Figures 6 and 7. The average number of elements correctly placed with respect to a "best fit" grading system are depicted. The "best fit" system allows for separation of the recognition and registration problems inherent with pattern matrices. Briefly, "best fit" grading consisted of finding the best fit between an overlay of the actual pattern and the subject's response. The subject was given a correct grade if, after the largest number of elements were exactly fit, any other element was correctly placed with respect to one coordinate and differed by, at the most, one position in the other coordinate. This method of grading is highly artificial. However, all the grading in the experiments was consistent, and very little difficulty arose on the grader's part in making an appropriate grade.

As expected, performance was decidedly better with the "structured" patterns of both the (5)- and (10)- element set, than with the "random" patterns from the same sets (as can be seen by comparing the groupings in Figure 5 with the scores in Figures 6 and 7). This experiment clearly demonstrates that even at very short duration exposures, highly structured material can be recalled within the span of immediate memory with relative facility. The saturation of this span of immediate memory is evident from the asymptotic behavior of the curves for long duration exposures. It is interesting to note that some patterns actually suffer a deterioration in performance in going from exposures of 20 to 50 frames. Perhaps the subject begins to saturate his immediate memory with information at about 20 frames and "forgets" during the remaining two seconds before he is allowed to make a response. Exhaustive analysis of the data shown in Figures 5, 6, and 7 lends support to several general concepts of recognition. These are summarized in Figure 8. Figure 8 shows typical "best fit" grades versus duration for "random" and "structured" patterns from each of the (5) - and (10) - sets. In general, there is a smaller difference between "random" and "structured" patterns of the (5)-set for short duration exposures than for the (10)-set. Note also that, in general, subjects do much better with "random" (5)- patterns than with "random" (10)-patterns. These figures illustrate that while the actual number of elements, which can be correctly perceived, on the average improves with the number present, (at least for 5 and 10 filled-in elements out of 108) there are distinct features of the response to a pattern considered "random" as opposed to a pattern considered "structured". Almost all "structured" patterns in the (5)- and (10)-set are characterized by a relatively slow improvement of performance with increasing duration until an abrupt increase in performance occurs. Beyond the duration for which this increase occurs, there is little or no improvement with increased exposure. The curves presented in Figure 8 are typical curves; if one selects and averages only the highly "structured" and highly "random" patterns of each set, curves very similar to those shown in Figure 8 result.

The delay in reaching the point of improved performance for "structured" patterns of both sets is considered to be related to the latency in eye motion involved in scanning these relatively large exposed patterns. A greater discussion of eye motion and psychophysics is presented later in this writing.

3. A Sampling Experiment and Some Aspects of Short-Term Visual Memory

The total report experiments, described in the previous section, all demonstrate the saturation of the span of immediate memory for relatively short duration exposures and relatively complex stimulus material. Since it is obvious that all subjects see many more things than they are able to report, we conclude there is much more information available in these short duration visual exposures than can be recalled in such total report experiments.

One way to surmount the difficulty of saturation of the span of immediate memory in psychophysical experiments is to use experiments which require partial report by the subjects. Several examples of such experiments are reported in the literature. [2,3,4] Some particularly comprehensive experiments regarding sampling of the information available in short-term visual presentation are reported by Sperling [5] and by Averbach and Coriell.[6] In addition to these relatively recent experiments on sampling techniques for psychophysical report of visual information, a comprehensive measurement of the role of short-term memory in vision has been presented by Averbach and Sperling.[7] These researchers have demonstrated that the visual process involves a high capacity buffer storage with essentially instantaneous information readin and relatively slow information readout. This buffer storage has been demonstrated to be susceptible to erasure and confusion. In general, its capacity, as inferred by sampling measurements, is very high compared to the normal amount of information which one measures in visual transmission experiments of the type previously described. It is this short-term memory which is under investigation in the sampling experiment to be described.

An exposure sequence, as shown in Figure 9, was used with the motion picture technique. This exposure sequence was used in connection with the (5)-element patterns -- J, F, and B, and the (10)-element patterns --6, 10, 3, and 8. The subject was exposed to one of these patterns for a duration of 10 frames (approximately 3/4 of a second). We conclude from our previous total report experiments that, during this interval, the subject is able to essentially get about as much information from the pattern as he can report with total report. Following the 10 frame exposure of an actual pattern, the blank matrix appears on the screen for a variable delay time. Following this delay time, a pair of possible elements from the pattern is exposed. These pairs are chosen such that one of the two elements in the pair corresponds exactly to an element in the pattern. The second element either corresponds exactly to a second element in the pattern, or differs from it in the same way that would result in an incorrect answer by the "best fit" grading technique used in the previous experiments. Ten sample pairs were used for each pattern at each of the delay times tested. A typical set of sample pairs for the pattern J appears in Figure 10.

The subjects were required to indicate verbally, after each pair was shown, whether the pair was taken exactly from the pattern or not. We can deduce from the percentage of sample pairs correctly reported for a given pattern (and delay interval) that the subject has correctly mastered, in a "best fit" sense, the relative positions of a given number of elements from the pattern. If we call the percentage of sample pairs correctly reported, S_c, and the number of elements which the subject has correctly related in reporting this number of sample pairs, n_c, these two quantities are related by Equation 1.

$$S_c = \frac{200}{n(n-1)} \sum_{k=1}^{n_c - 1} k \qquad (1)$$

where S_c = the percentage of samples correctly reported,

n = the number of elements in the pattern,

and n_c = the number of elements which must have been correctly related by the subject to achieve the level of performance indicated by S_c.

Equation 1 is derived by considering the total number of possible pair-wise relations that exist in the pattern versus the percentage which the subject is able to correctly report. Again, this technique for grading is artificial-- but consistent with the previous grading techniques for comparison purposes.

The results of the comprehensive sampling experiment conducted with the 7 patterns discussed earlier are shown in Figures 11 and 12. In these figures, the implied number of correctly related elements, n_c, are plotted versus the delay time between pattern and sample. From the curves shown in Figure 11, it is apparent that the "structured" patterns, J and F, suffer virtually no deterioration in performance with increased delay, while the "random" pattern, B, begins to experience a reduction in performance as delay time increases. Plotted on the same curve for reference is the performance in terms of number of elements correctly reported in a "best fit" sense for the 10 frame exposure duration. These reference lines indicate that, in short-term memory sampling experiments, performance is well above the level of performance connected with a similar task in a total report experiment.

These comments are more vividly illustrated by Figure 12 which presents the same sort of results for the (10) -patterns used. Here it is shown that the "random" patterns 6 and 10, suffer very sharp deterioration from levels above the total report level with increasing delay; while the "structured" patterns 3 and 8, experience virtually no change in performance-- in each instance staying substantially above the total report level.

There are at least two experimental artifacts in the conduct of this experiment which require discussion here. First of all, the simpler patterns, i.e., the highly "structured" patterns, are exposed a large number of times in order to permit the use of 10 samples at each of the 3 or 4 delay times tested. The amount of information transfer between exposures is undoubtedly significant. It is this information transfer or remembering which contributes to the lack of deterioration with increased delay. On the other hand, the same amount of information presumably may be transferred for the "random" patterns. It is clear that with these "random" patterns no such prolonged memory exists.

The major points to be made with this experiment are two. The first is that such a sampling experiment does result in an information retrieval by the subject above the level for total report in all cases. The second point is that the compression in performance among the "random" and "structured" patterns of both the (5)- and (10) - set for very short delays indicates that the short-term memory involved in this experiment is at least partially eidetic or pictorial. In other words, in the short-term memory information is evidently processed from the pattern as if it remained vivid and uncoded by the subject. For this reason, the "random" and "structured" pattern groupings are less reliable in their indication of performance level for very short exposures.

The great difficulty in terms of the total number of exposures required to demonstrate these phenomena render this technique relatively useless for more comprehensive experimentation. It should be pointed out that the grades reported in Figures 11 and 12 are based upon the number right minus the number wrong divided by the total number shown at each point. In other words, guessing has been corrected for in the conventional manner. This guessing correction factor further attributes to the odd shape of the curves for patterns 6 and 10 in Figure 12.

4. Eye Motion Measurements in Connection with Psychophysical Experimentation

The patterns used in the experiments described above subtend angles to the subject, at least in the horizontal direction, of about 10 degrees. Such patterns might be considered large from the point of view of the eye's foveal angle, and thus, presumably would require some gross eye motion in order for the subject to "see" and correlate various features of the pattern. A simple device developed by Stark and Sandberg[8] from the original paper by Richter and Pflatz[9] to measure horizontal eye motion was used in connection with some 1 x 6 matrix patterns having essentially only a horizontal extent.

In a typical measurement situation the subject was seated six feet from a curved screen. The subject's head is held rigid in an ordinary baseball "catcher's mask". A pair of clear plastic goggles are placed over the subject's eyes. These goggles contain the light sources and reflection measurement sensors. Figure 13 depicts the measurement configuration. A dual track chart recorder was used to monitor the short duration light flashes and the dc signal proportional to horizontal eye position.

The results of this measurement program are summarized below. A complete description of the measurements including sample Sanborn recording traces are given in the author's disseration. [10]

1. No significant eye motion (none greater than 1-1/2 degree) occurs during exposures up to 100 milliseconds duration. In general, latency increases as the flash duration is decreased. The average latency for 100 millisecond flashes is about 240 milliseconds as opposed to 275 milliseconds for 30 millisecond flashes. The latency is shorter when position-only displays are used (averaging about 175 milliseconds).

2. Post-exposure eye motion differs in accordance with the stimulus material. Numeral plus position displays are followed by greater motion almost invariably involving a center-to-right-to-center-to left-to-center sequence, with maximum excursions of about 3 degrees right of center to 2 degrees left of center and fixation intervals varying from 150 to 700 milliseconds. A typical post-exposure motion sequence recorded from one subject's response is shown in Figure 14. Position-only displays are characterized by less post-exposure motion almost invariably between the center and right (2 degrees). This motion takes place much more slowly than comparable excursions with numerals. (It is <u>not</u> <u>saccadic</u>.)

3. At 60 millisecond exposure durations with position-only displays virtually no motion is recorded except a very slow drift less than 1/2 degree in amplitude. This combination of stimulus and exposure duration results in the highest error rate for psychophysical experiments reported by the author [11] with the 1 x 6 position-only display.

Thus, in interpretation of the psychophysical performance with the patterns referred to in earlier experiments, it is a reasonable assumption that voluntary gross eye motion is not involved as such for exposure durations less than about 4 frames.

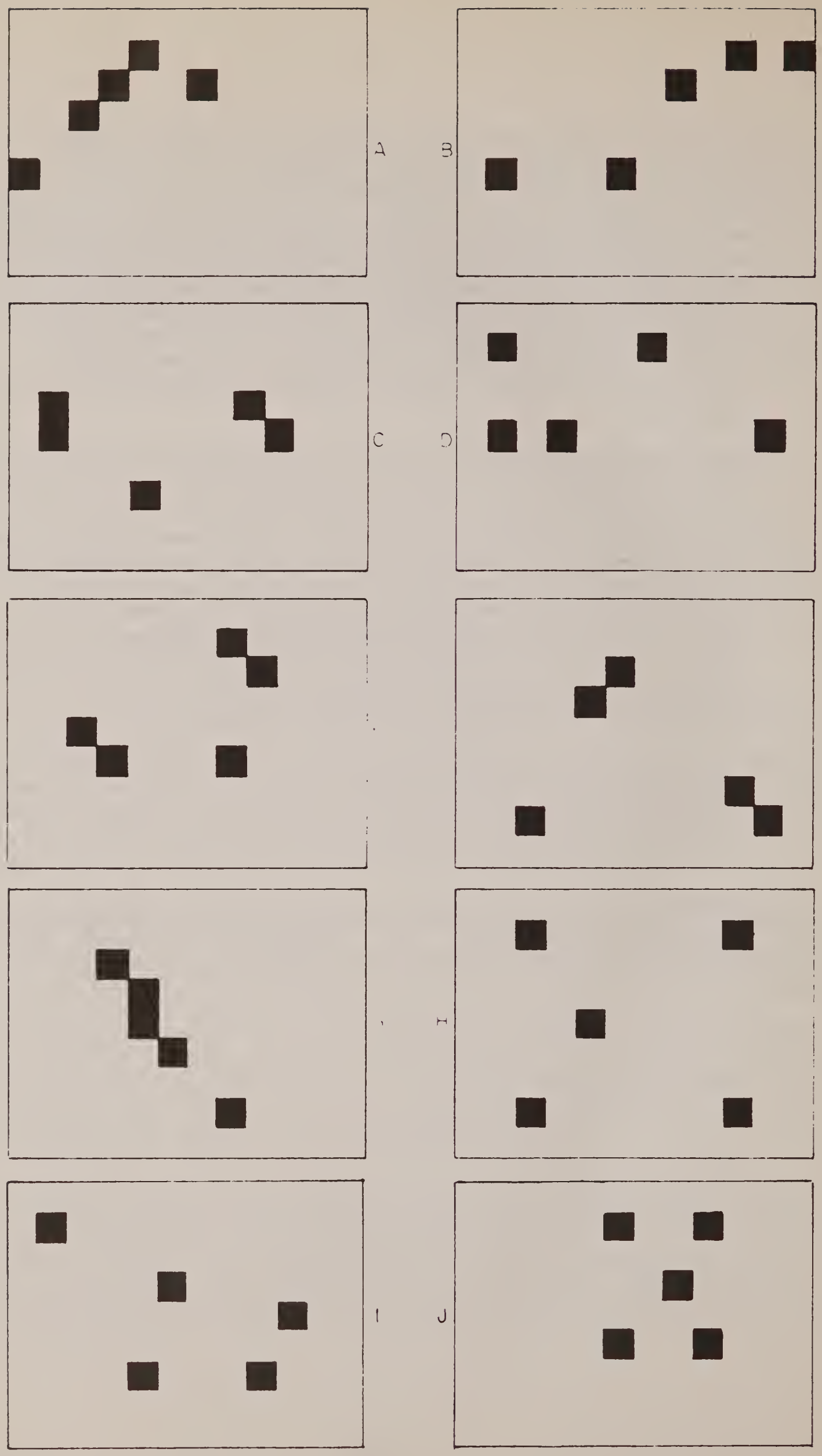

Figure 1
(5) - Patterns

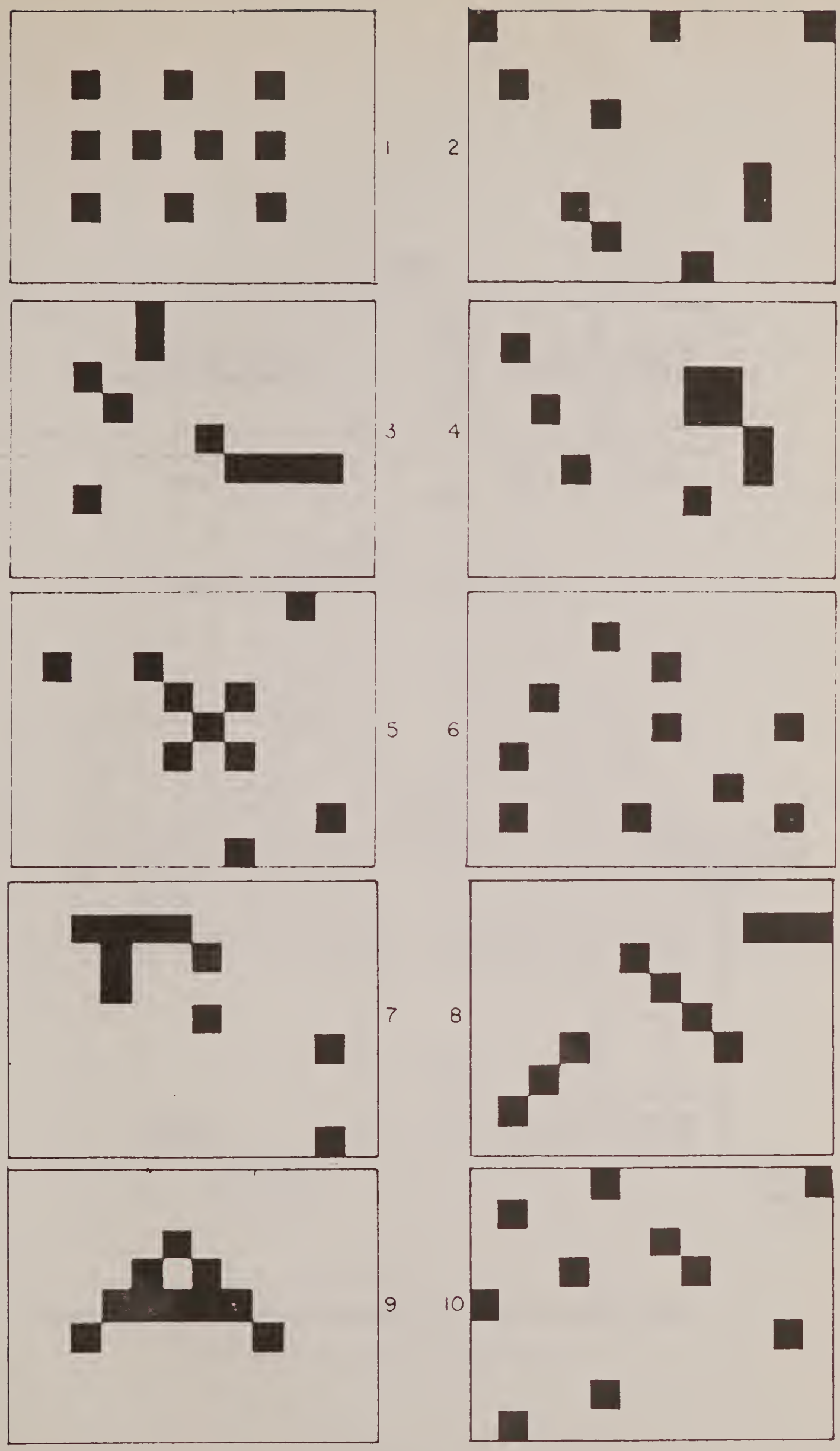

Figure 2
(10) - Patterns

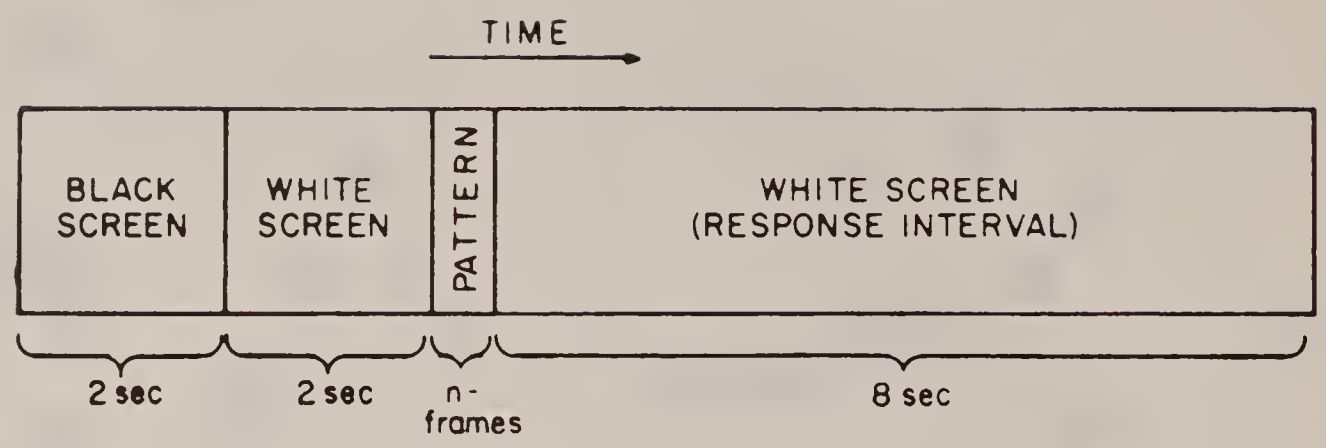

Figure 3

Typical Motion Picture Pattern Exposure

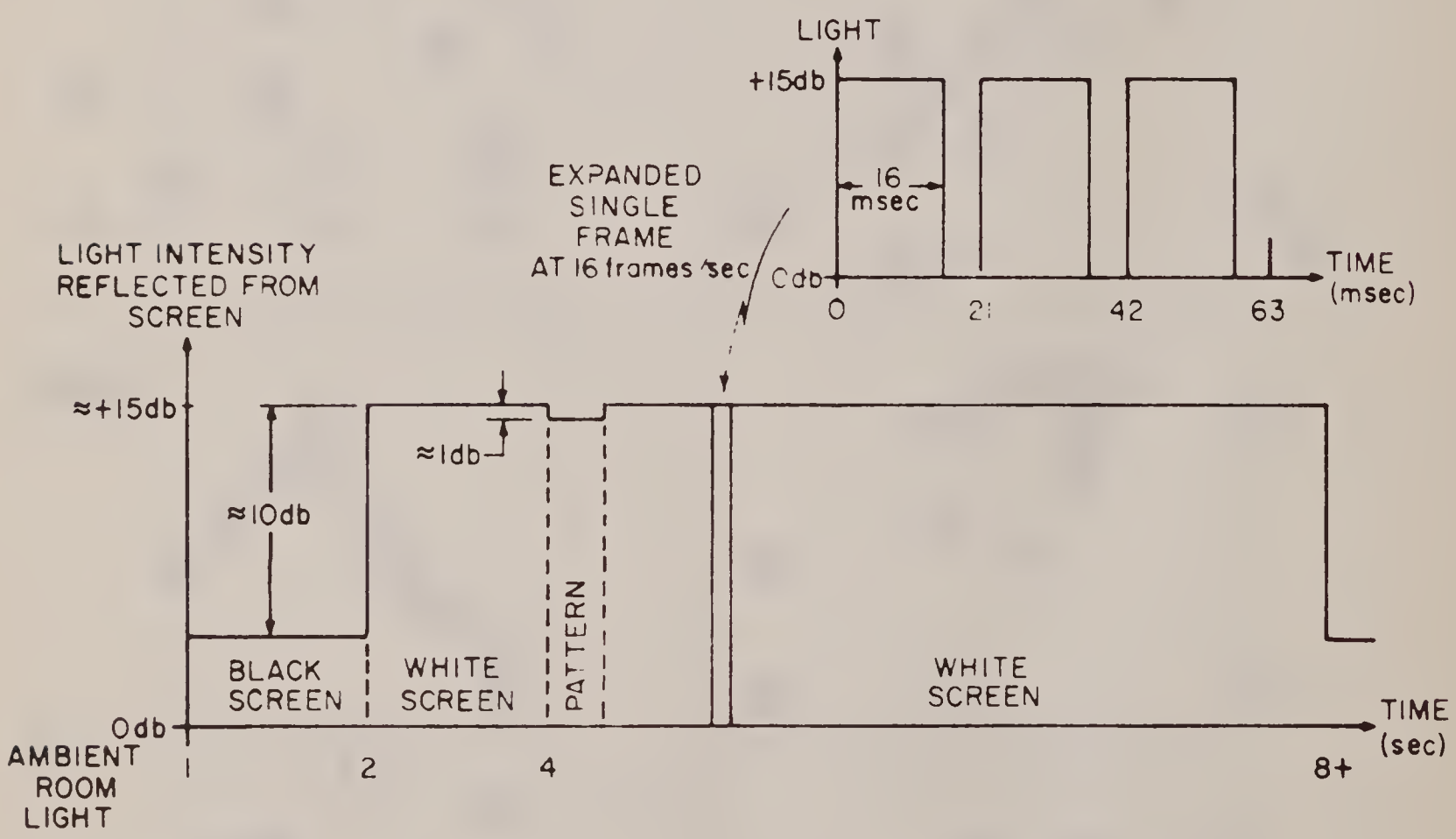

Figure 4

Light Versus Time During A Typical Motion Picture Pattern Exposure

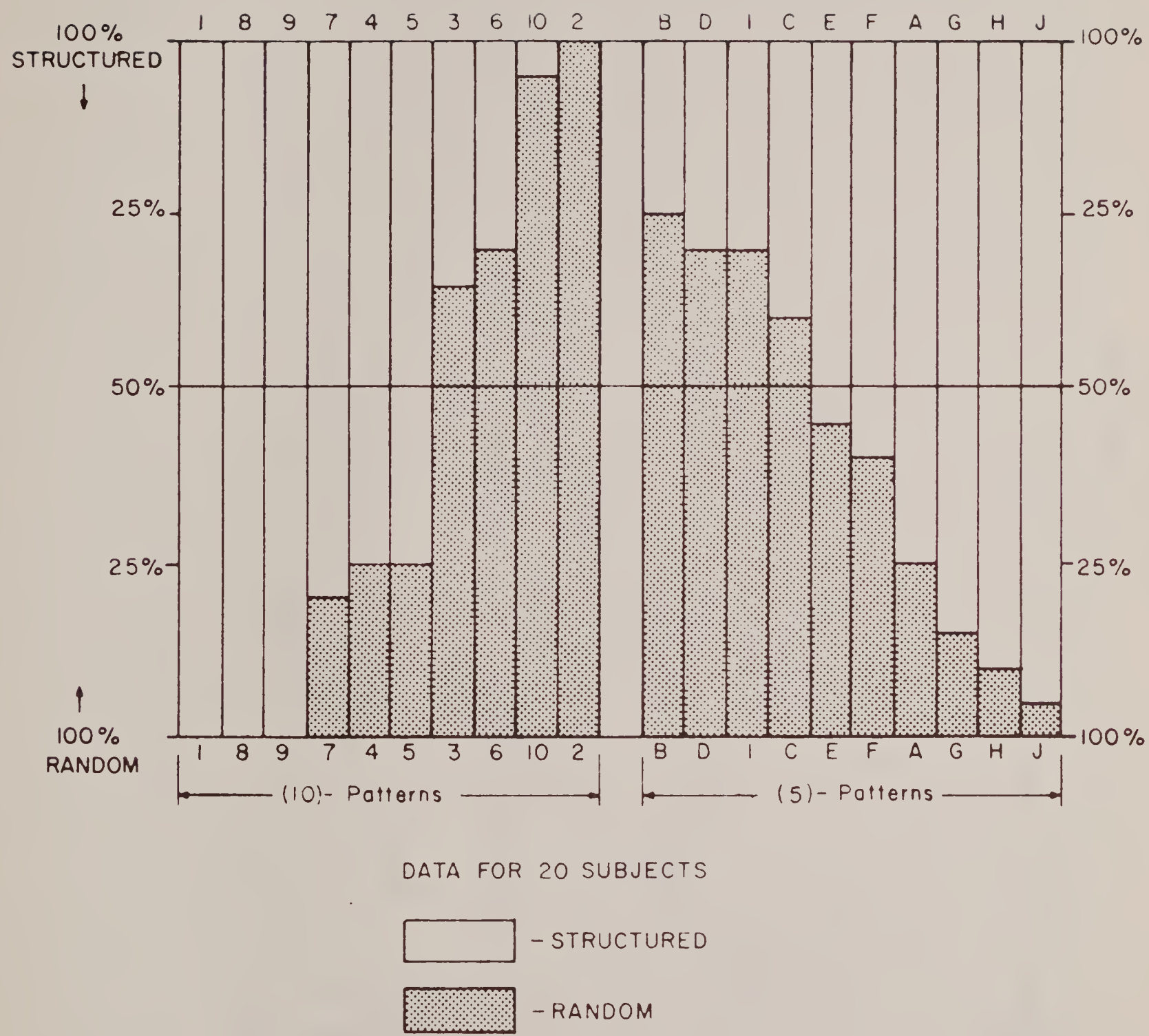

Figure 5

Classification Of Patterns - Experiment I

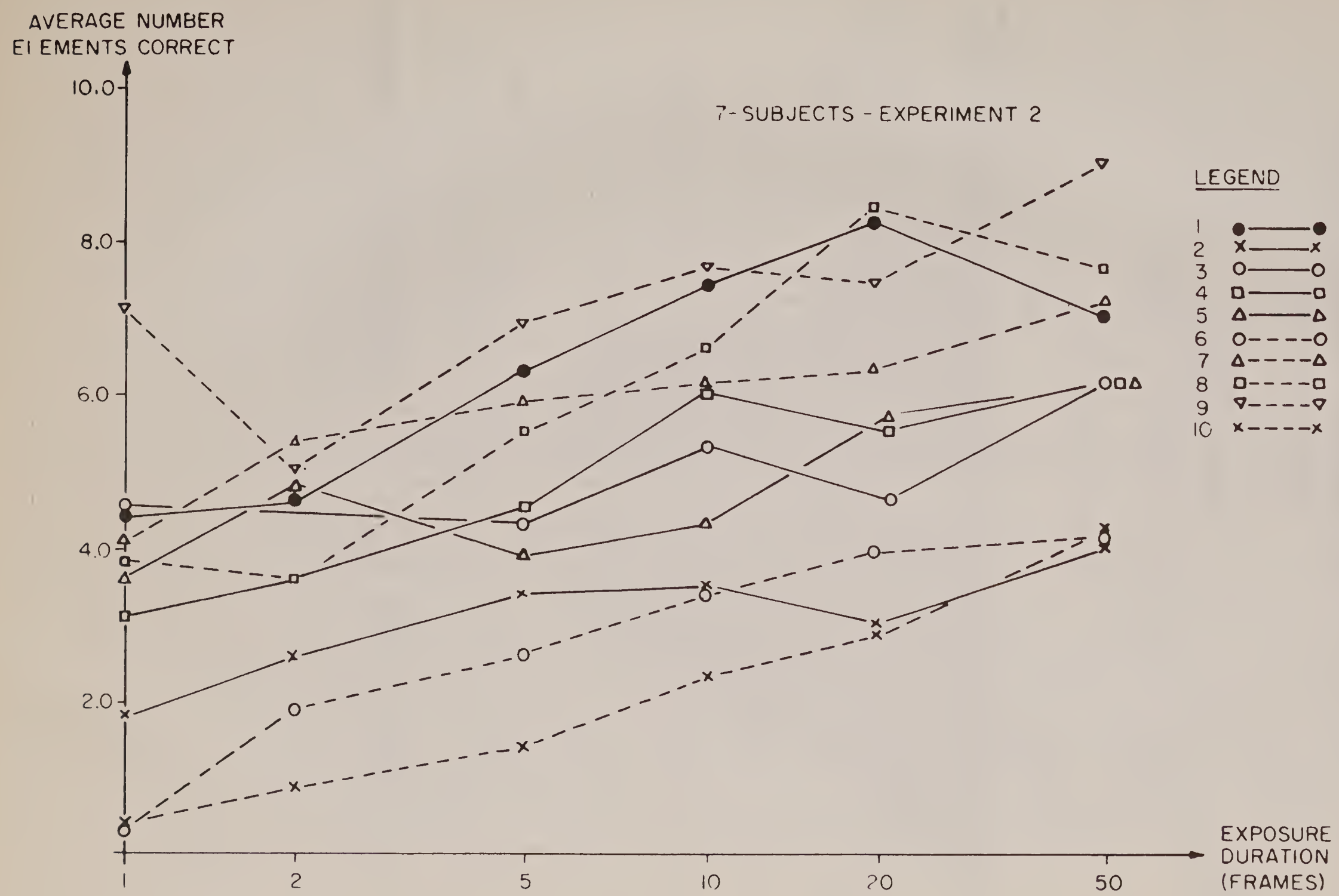

Figure 6

(10)- Patterns - Best-Fit" Data

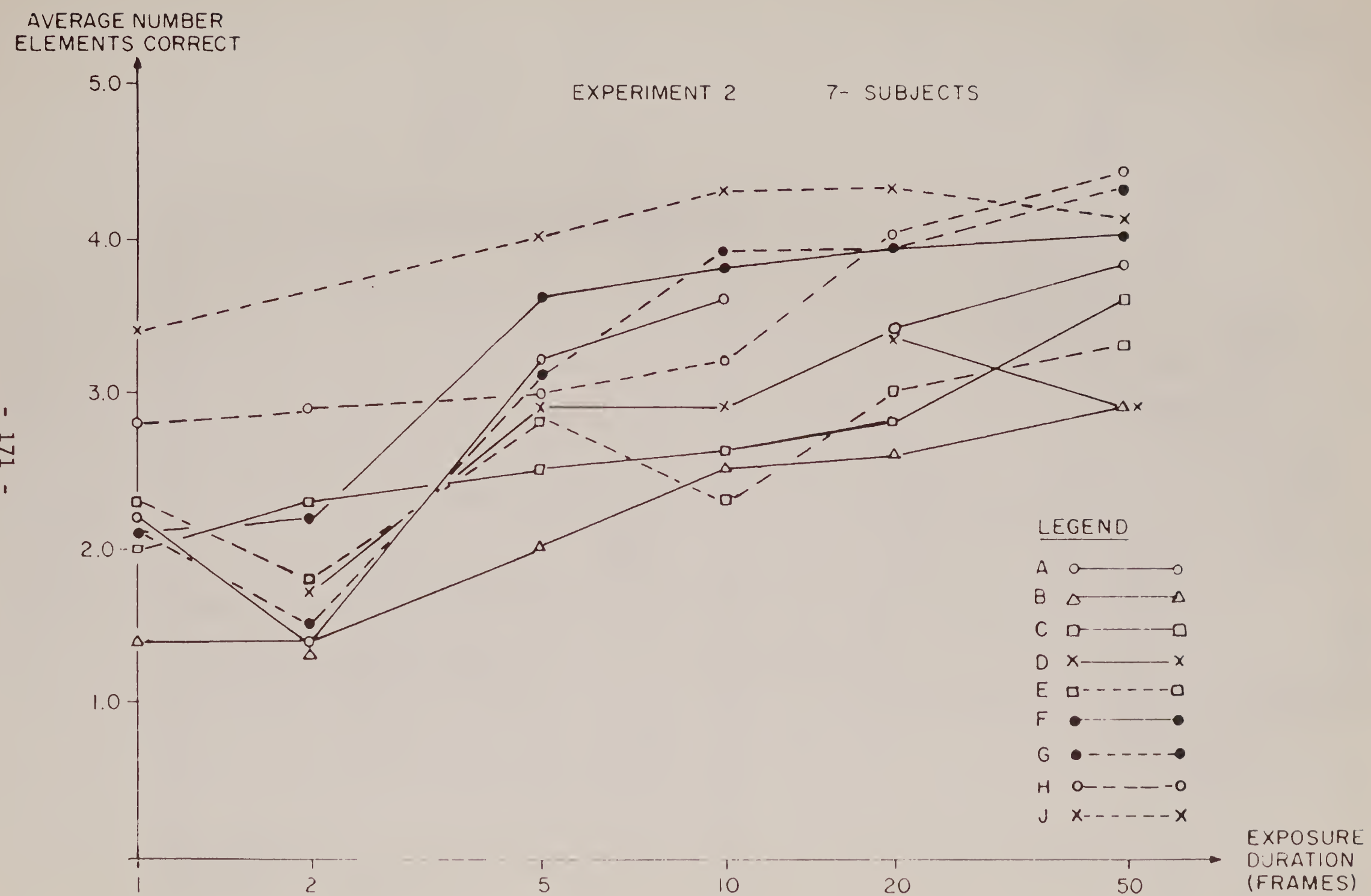

Figure 7

(5)- Patterns - "Best-Fit" Data

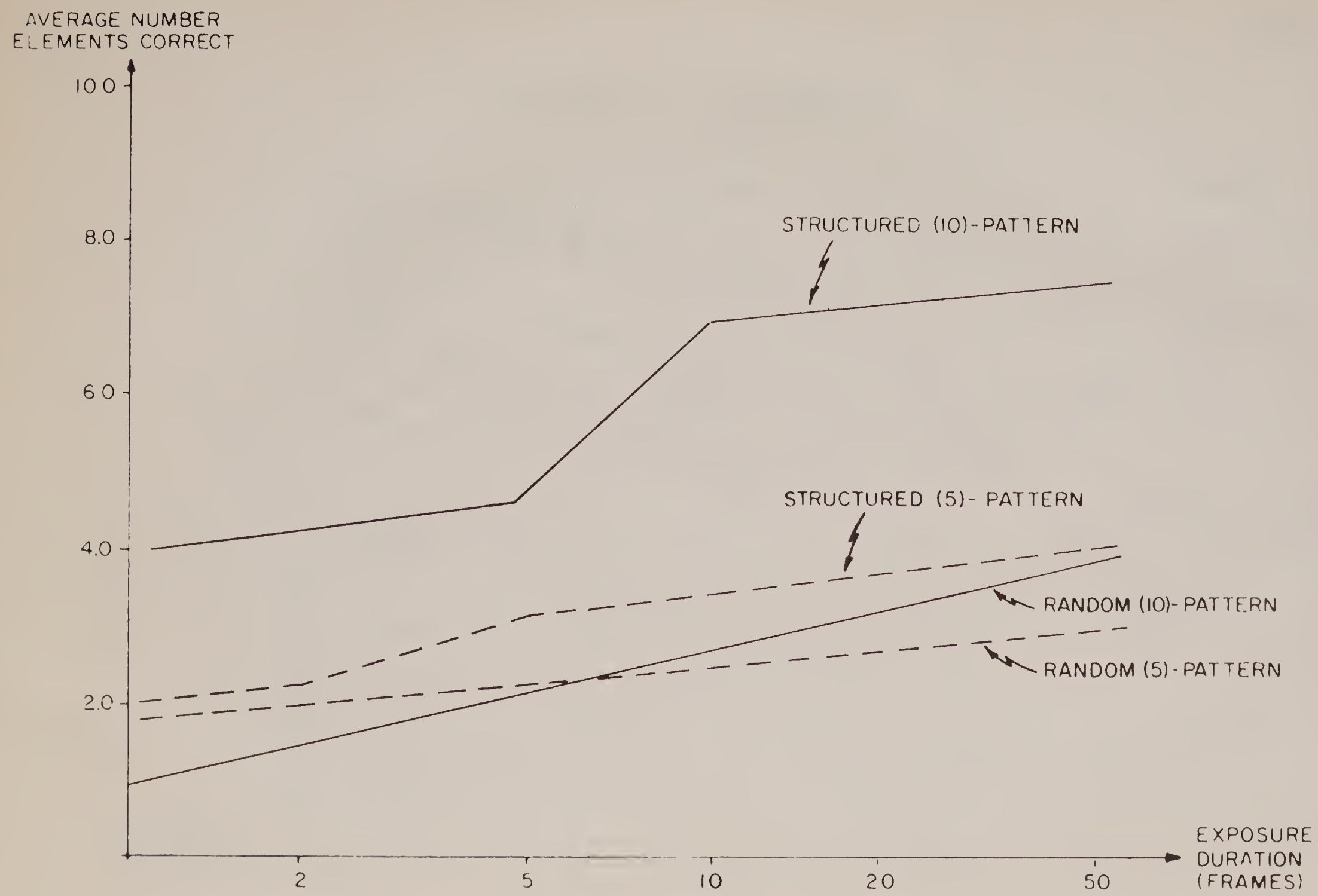

Figure 8

Typical "Best-Fit" Grade Versus Duration Curves

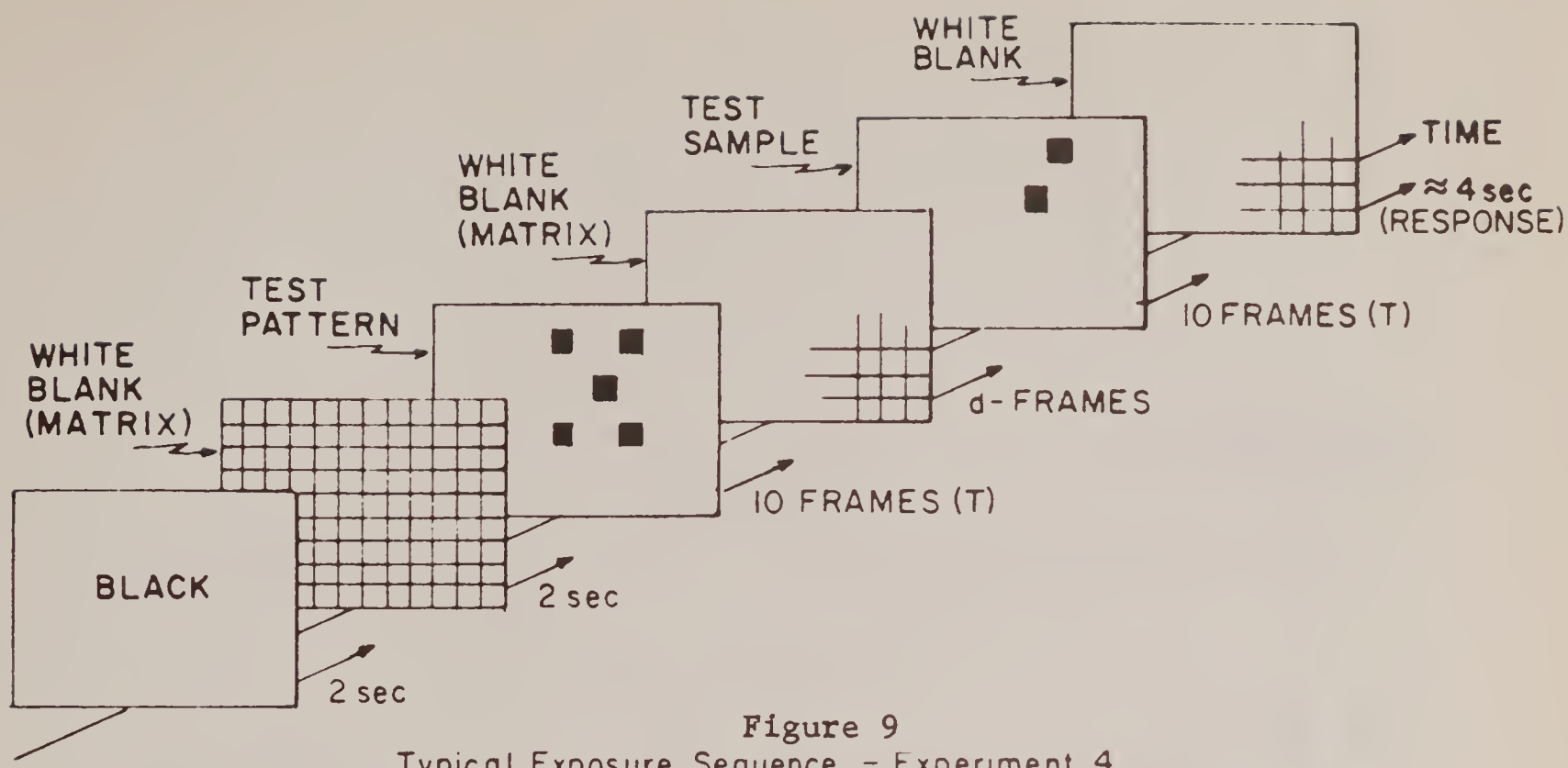

Figure 9
Typical Exposure Sequence - Experiment 4

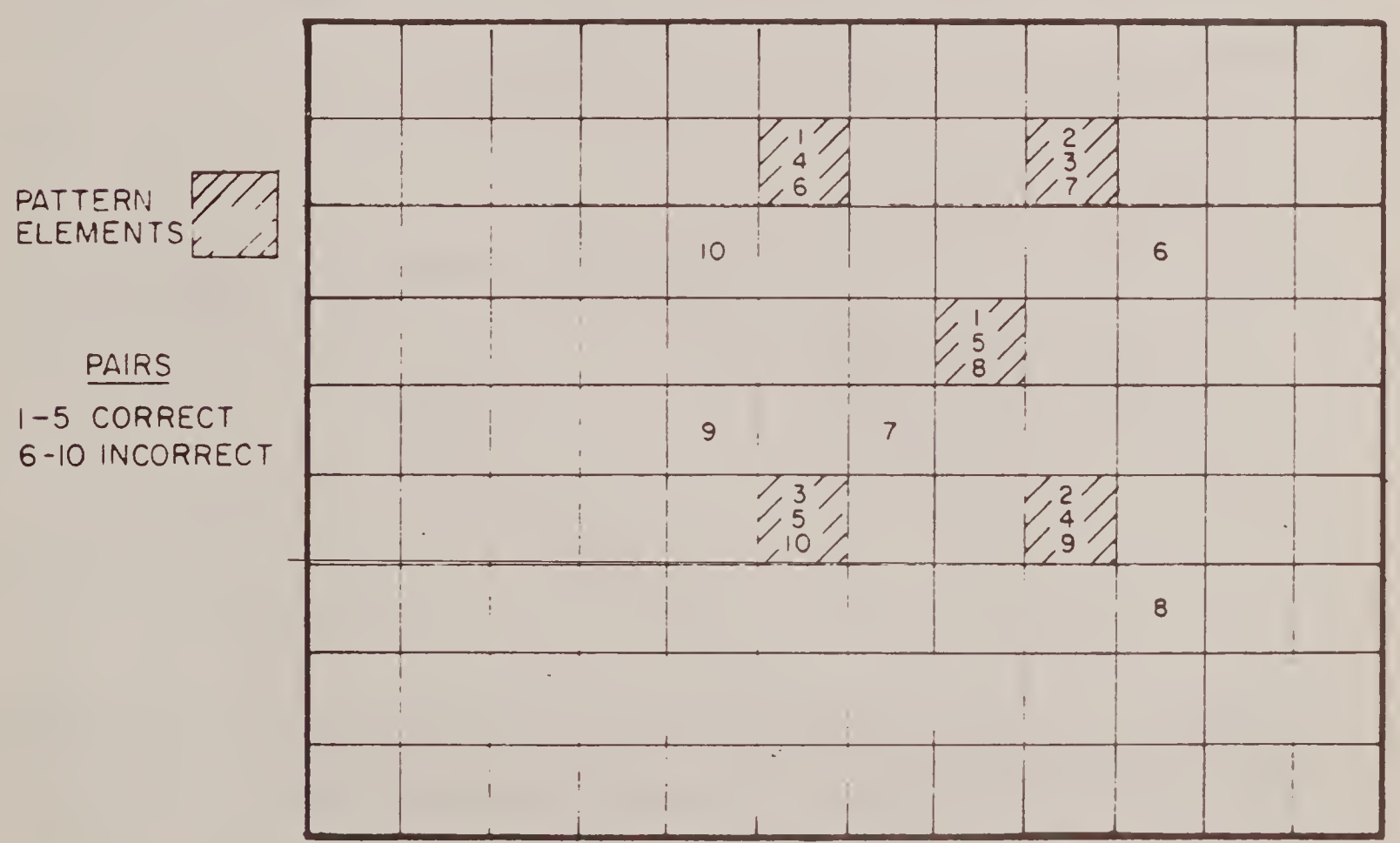

Figure 10
The Ten Sample Pairs For Pattern "J"

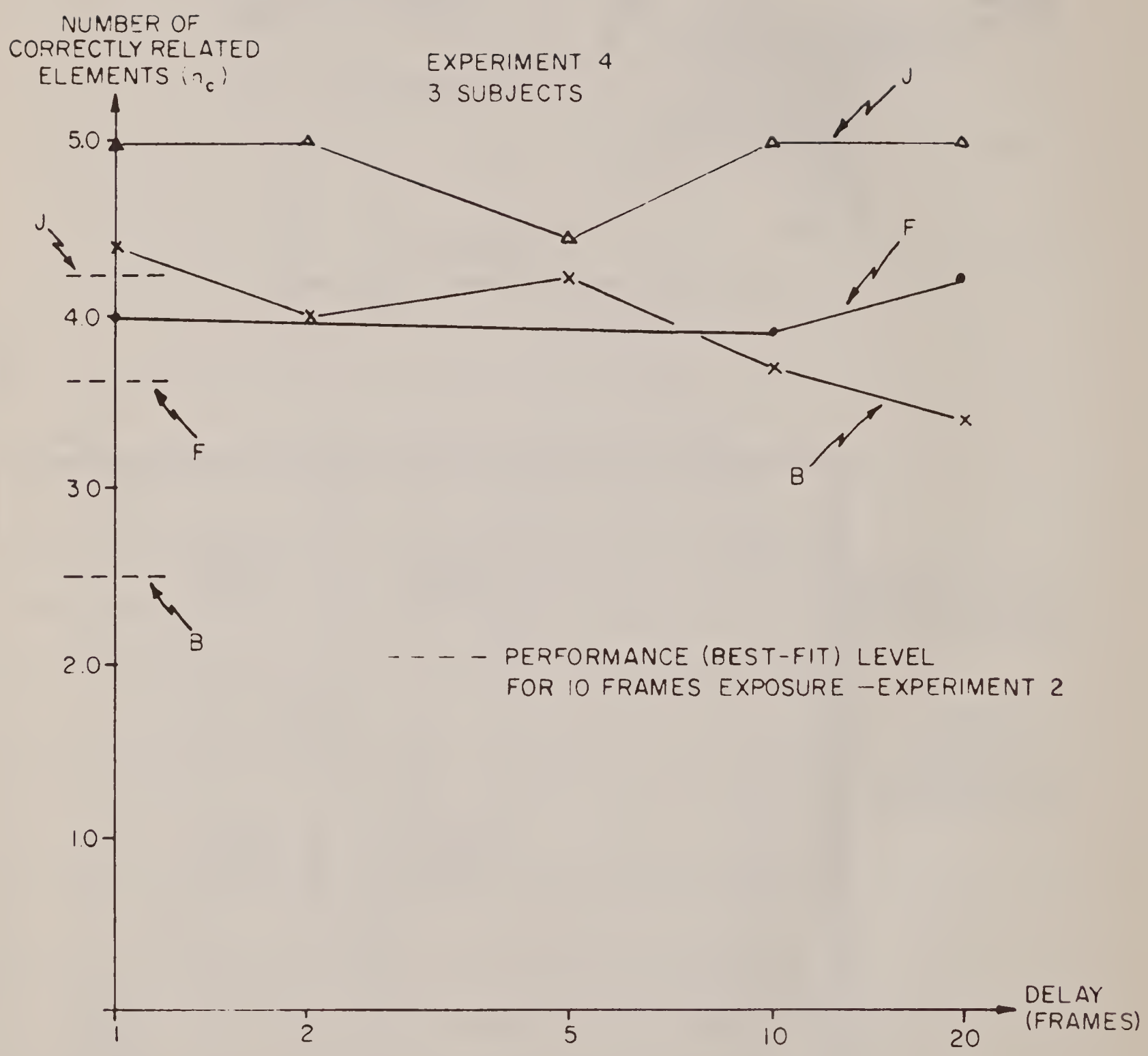

Figure 11

n_c Versus Delay—Sampling Experiment
(5) - Patterns

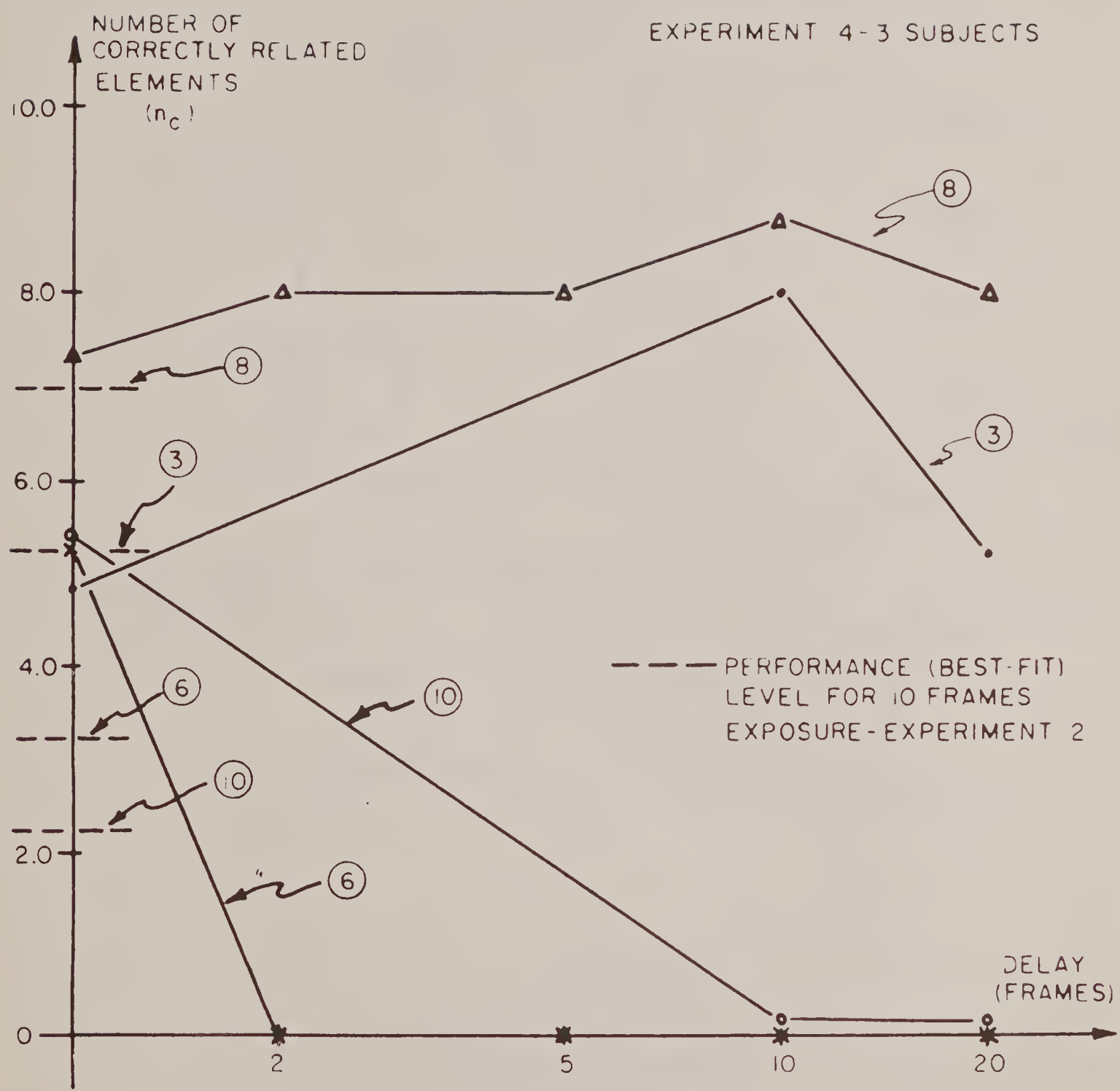

Figure 12

n_c Versus Delay-

Sampling Experiment

(10) - Patterns

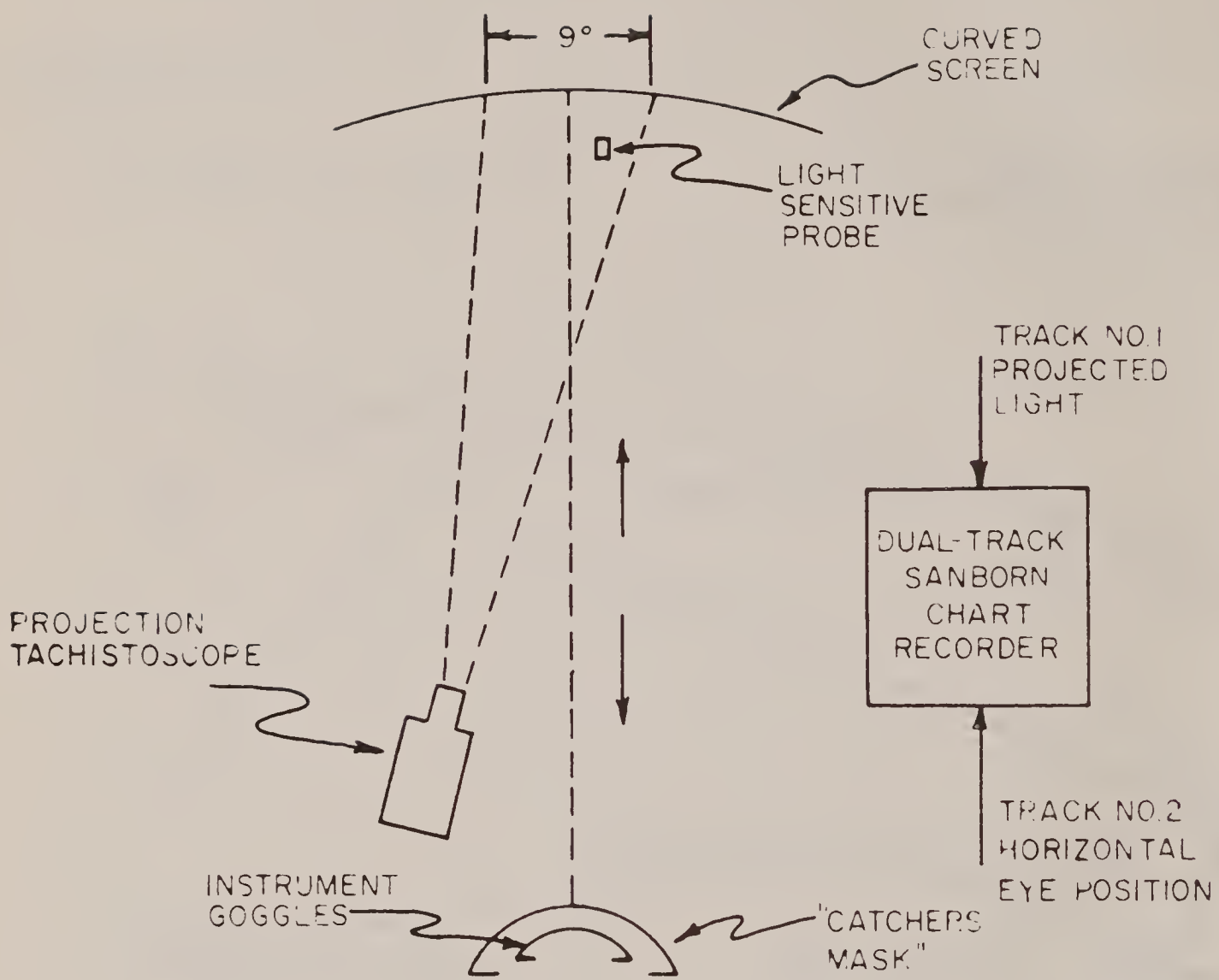

Figure 13

Horizontal Eye Motion Measurement Configuration

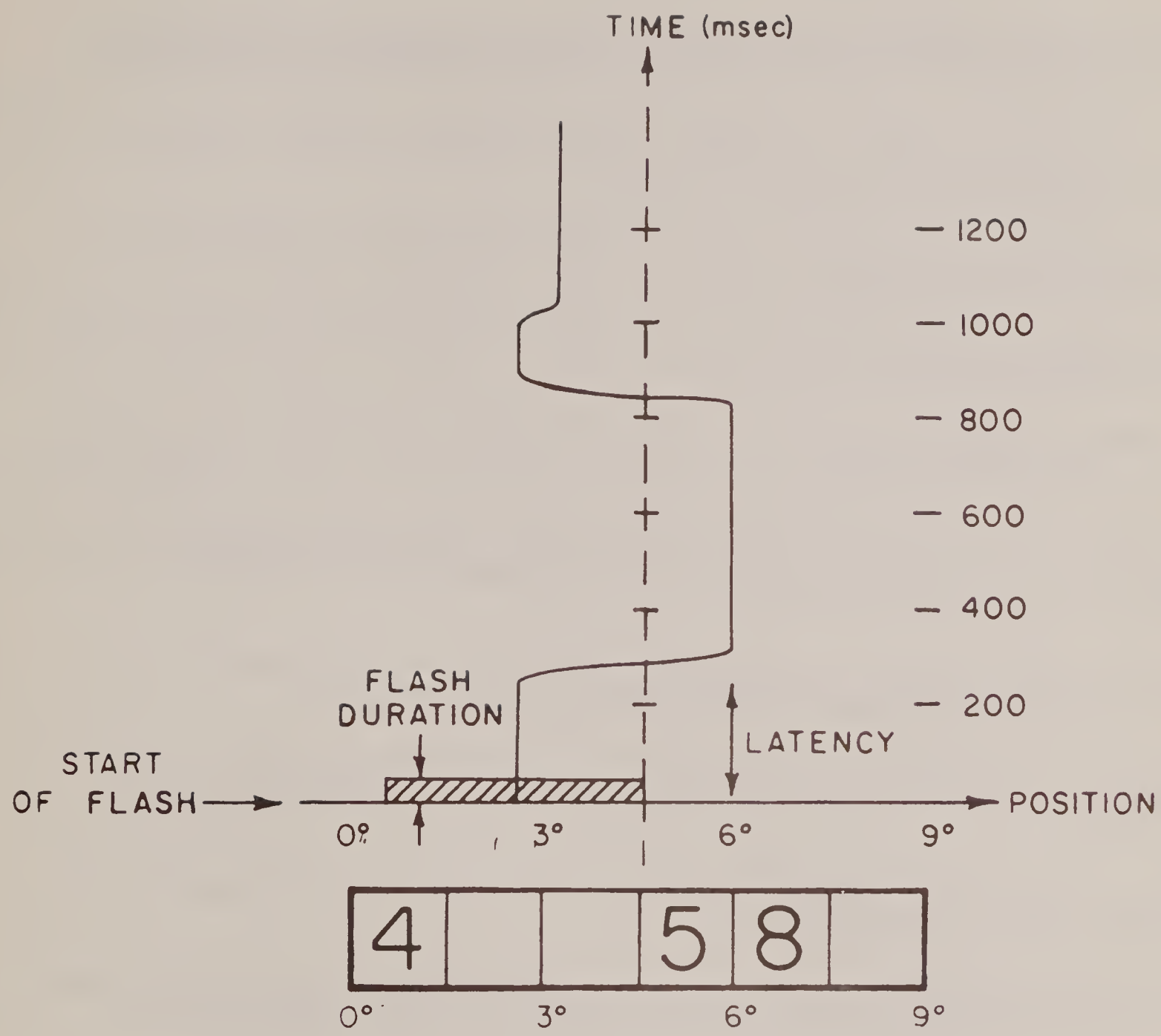

Figure 14

Eye Position Versus Time
Numeral Plus Position
Display

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VISUAL CENTERS WITHOUT END ORGAN STIMULATION

Carl Kupfer, M. D.

Abolition of end organ stimulation has been observed experimentally by rearing young or old animals in the dark and clinically in conditions such as a sensory amblyopia (supression of vision secondary to opacity of the ocular media, viz. cataract), retinal pathology causing localized destruction and removal of the end organ surgically, i.e. enucleation.

The experimental data as presented has been poorly controlled and conflicting with respect to species variations. No systematic study has been made of the lateral geniculate nuclei in either the experimental material or in clinical cases of sensory amblyopia for either morphological, biochemical or physiological changes, except in a few cases of enucleation.

Work is being directed toward studying the pattern of transsynoptic atrophy in the lateral geniculate nucleus following localized retinal lesions in humans. It is hoped that a detailed description of the retinal representation upon the lateral geniculate nucleus may clarify the function of this structure.

CONCURRENT SESSION B-MORNING SESSION
THURSDAY, October 12, 1961, Bush Room

Dr. Eugene F. Murphy, chairman for this session, welcomed the participants and noted that the meetings in the Bush room were but part of the conference, concurrent sessions being held at the Research Laboratory of Electronics in an adjacent building. He then pointed out that the present conference was a result of concurrent plans by AFB to hold a conference on mobility research and by the VA to hold one on mobility devices. It seemed logical to hold one joint conference.

The October 12 session in the Bush room was intended to give invited researchers from other fields some background in mobility of the blind, the magnitude of the problem, the light cane, the dog guide, and the mobility devices developed over the years. Dr. Murphy recalled the pioneering part played by Dr. Vannevar Bush in this field when he stimulated formation of the Committee on Sensory Devices. Dr. Murphy then indicated that the final day's sessions would be held jointly with the other participants and that he was hopeful of productive discussions. He regretted he would be unable to attend, particularly in view of his interest in evaluation of devices, one of the scheduled topics for the final day.

Dr. Murphy then suggested it might be unrealistic to expect any device to be acceptable to 90% of the blind population and that low acceptance rates may have plagued otherwise reasonable devices in the past, stifling their full development. He cited the low utilization rates for the cane, the dog guide, and in some instances the elbow of a sighted person, all useful and successful mobility aids for those persons who use them. The chairman then said he hoped to get some new ideas from those familiar with other fields: guided missiles, inertial navigation, stable platforms, infra-red sensors, human engineering, extraction of information from images, etc. He pointed out that although the size and cost of instrumentation is usually beyond the practical limits for aid devices, ink print reading machines, regarded as somewhat fantastic in 1949 and even in 1954, have now become realities. They are still expensive, but are fairly widely used for special applications.

Dr. Murphy then briefly mentioned the work of Mr. Hans Mauch who is developing a relatively portable reading machine for the blind. He expressed the hope that similar work could be fostered in the mobility area. Such work provides respite to some scientists engaged in work which may lead to mass destruction. It thus serves a defense function by bolstering the effective manpower posture of the nation, and is of inestimable value in creating international good will.

Dr. Murphy said that no technical guidance device competes with either the cane or the dog. Devices are intended either to supplement existing aids or to help overcome the objections of persons who do not use a cane or a dog.

The chairman then called on Dr. Eric Josephson to tell the group something about the magnitude of the problem and provide some statistics on the blind population, their mobility, and their activities.

Dr. Josephson emphasized that the statistics shown in the tables (reproduced here on pages 183 to 198) concern selected population characteristics. There has long been a dearth of reliable statistics on blindness. Workers for the blind have been unable to agree on a definition of blindness, the blind population is comparatively small and widely scattered, and no single agency has been responsible for collecting statistics on blindness. Until 1930 the United States did seek information about blindness in the decennial census, but it has since dropped the practice. Current statistical treatments are thus based on sample surveys or estimates. There are three major sources of information at the present time: 1) The U. S. National Health Survey; 2) Registers maintained by the individual states (the basis on which Dr. Ralph G. Hurlin of the Russell Sage Foundation made his well known estimate in 1952 that there were 308,000 blind persons in the continental United States) and 3) Sample surveys conducted by agencies.

The incidence of blindness as estimated by Dr. Hurlin, is 1.98 per 1000 in the general United States population, with a high of 3.42 per 1000 in New Mexico and a low of 1.40 in Utah. In 1959 the U.S. National Health Survey estimated a rate of about 6 blind persons per 1000 population. The reason for the difference in these estimates reflects the difference in the definitions of blindness used. Table I shows the prevalence of blindness in three states and in the United States as a whole. It also clearly shows that the blind as a population group are elderly. This is perhaps the most important social characteristic of the blind.

Table II presents some crude classifications of types of activities of blind persons. It is important to note the percentage in each column listed as working. Table III, which really has little to do with blindness, offers statistics on the limitation of mobility due to chronic conditions. In Table IV "Visual impairments" includes both the blind and those not blind but visually impaired. This report suggests that there are approximately 100,000 visually impaired persons 45 years old and over who have major limitations in mobility.

Table V has to do with mode of travel reported in two surveys of the blind. An important point is that one column is based on primary mode of travel while the other two combine primary and secondary modes. In studying travel among the blind, it is necessary to make distinctions between primary and secondary modes because many use more than one mode of travel. The "other" mode of travel listed in this table was usually found to be the use of a wheel chair.

In Table VI the degree of vision is based on a self-rating of blindness using the scale shown. This scale correlates quite well with clinical examination. Travel Vision as used here connotes visual acuity sufficient to enable recognition of persons by sight. Tables VII to XI describe various correlates of mobility - including vision, age, education, employment and general physical condition. The concept of activity, presented in Tables XII to XVIII, is important. "Activity" is by no means intended to be a synonym for "mobility," and in Table XII, the weighting scheme for defining this factor is shown. There seems to be little relation between amount of travel vision and activity, but age and education play a significant part (See Tables XIII and XIV). Table XV deals with family income; as might be expected, the greater the income, the greater the activity as measured by the chosen criteria. Similarly, Table XVI shows an expected relation between activity and general physical condition. There seems to be no significant difference in activity of groups having different attitudes toward blindness as shown in Table XVII. Dr. Josephson said that conspicuously absent here is a table correlating activity with mode of travel. The data on hand show no relation between activity and mode of travel, but on the other hand there are substantial differences in activity according to whether the person has received travel training (Table XVIII).

Dr. Josephson said this group of tables may give only a small part of the answer as to the population which needs the help of the researchers and of agencies for the blind. There are still too many variables and unknowns to come up with a precise figure. As an estimate he said there are approximately 100,000 persons 45 years old or older who have some major limitation in mobility, including both the blind and those not blind but visually impaired. In addition the National Health Survey estimated over 400,000 with partial limitation of mobility, suggesting a total population in excess of half a million. Figures from a survey by AFB indicate there are about 200,000 persons in the adult population who need some sort of training in mobility techniques.

Table I

Age Distribution of the Visually Impaired in Selected Areas

Age Group	U.S. "Blindness" (1957-8)	U.S. "Other Visual Impairment" (1957-8)	New York (1960)	North Carolina (1960)	Mass. (1960)
Under 25	4.2%	12.9%	12.5%	12.6%	13.7%
25-44	6.1	15.8	12.9	16.6	13.7
45-64	21.1	30.9	25.3	24.5	24.0
65 and over	68.3	40.4	49.3	46.3	48.6
Number of cases	(958,000)	(2,064,000)	(28,369)	(12,246)	(8,238)

Note: The figures for the U.S. are derived from a national sample survey made by the U.S. Public Health Service in which a person was classified as blind if (a) he was 6 years or older and a negative response was given to the question: "Can you read ordinary newspaper print with glasses?", or (b) he was under 6 years of age (or was over 6 but had never learned to read) and was reported as blind or in terms indicating that he had no useful vision in either eye. Persons who were blind in one eye but had sight in the other, or who had poor vision or trouble in seeing in one or both eyes but were not blind, as defined, were tabulated under "other visual impairment." Source: U.S. National Health Survey. Impairments by type, sex, and age, United States, July 1957--June 1958. Washington, 1959. Figures for the three states are derived from reports of their respective commissions for the blind and they have been adjusted to conform to the intervals used in federal statistics on blindness. In each of these states, where the reporting of new cases of blindness is mandatory, blindness is defined as central visual acuity of 20/200 or less in the better eye, with correcting glasses; or central visual acuity of more than 20/200 if there is a field defect in which the peripheral field has contracted to such an extent that the widest diameter of visual field subtends an angular distance no greater than 20 degrees. In simpler terms, a person is said to have visual acuity of 20/200 if at a distance of 20 feet he can recognize symbols and objects which a person with normal vision can recognize at a distance of 200 feet. As for restriction of field, if it is such that he can see only a very limited area at a time and can make very little practical use of his vision, he will also be considered legally blind. It is important to note the difference between the definition of blindness used in the National Health Survey and that used by most states in determining eligibility for various benefits and services.

Table II

Major Activity of Visually Impaired in the U.S. (1957-8)

as Defined by the National Health Survey

Major Activity	Blind	Other Visual Impairment
School and preschool	3.4%	9.2%
Usually working	11.8	33.3
Keeping house	34.0	32.1
Retired	35.5	18.8
Other	15.2	6.5
Number of cases	(959,000)	(2,064,000)

Note: For definitions of "blind" and "other visual impairment" see Table I.
Source: U.S. National Health Survey. Impairments by type, sex, and age, United States, July 1957--June 1958. Washington, 1959.

Table III

Limitation of Mobility Due to Chronic Conditions

for Selected Age Groups in the U.S. (1957-8)

Limitation of Mobility	Age Group 45-54	55-64	65-74	75 & over
Persons with no chronic condition and with no limitation of mobility	43.1%	34.6%	24.4%	16.9%
Persons with one or more chronic conditions and no limitation of mobility	54.4	59.3	63.4	51.6
Persons with one or more chronic condition and partial limitation of mobility	2.0	4.5	9.8	22.8
Persons with one or more chronic condition and major limitation of mobility	0.5	1.5	2.4	8.8
Number of cases	(19,639,000)	(14,831,000)	(9,627,000)	(4,886,000)

Note: These figures, from the National Health Survey, are reported in U.S. National Health Survey. Limitation of Activity and Mobility due to chronic conditions, United States, July 1957--June 1958. Washington, 1959. "Chronic conditions" included: asthma, any allergy, tuberculosis, chronic bronchitis, repeated attacks of sinus trouble, rheumatic fever, hardening of the arteries, high blood pressure, heart trouble, stroke, trouble with varicose veins, hemorrhoids or piles, gallbladder or liver trouble, stomach ulcer, any other chronic stomach trouble, kidney stones or other kidney trouble, arthritis or rheumatism, prostate trouble, diabetes, thyroid trouble or goiter, epilepsy or convulsions of any kind, mental or nervous trouble, repeated trouble with back or spine, tumor or cancer, chronic skin trouble, hernia or rupture, deafness or serious trouble with hearing, serious trouble with seeing even with glasses, cleft palate or club foot, stammering or other trouble with speech, missing limbs or extremities, cerebral palsy, paralysis of any kind, and any permanent stiffness or deformity of limbs or back.

Table IV

Limitation of Mobility Among Persons 45 and over

with Selected Chronic Conditions in the U.S. (1957-59)

Limitation of Mobility	Condition: Paralysis of major extremities and/or trunk	Visual impairments	Heart conditions	Arthritis and rheumatism	Deafness and other hearing impairments
All ages 45 & over					
None	36.3%	75.8%	76.4%	88.5%	96.7%
Partial	36.9	19.3	18.7	9.5	2.7
Major	26.8	4.9	4.8	2.1	0.6
No. of cases	(612,000)	(2,353,000)	(4,046,000)	(8,920,000)	(4,270,000)
45-64					
None	41.8%	86.2%	86.5%	94.1%	98.1%
Partial	39.3	11.1	11.2	5.4	1.7
Major	18.9	2.7	2.3	0.5	--
No. of cases	(285,000)	(839,000)	(1,863,000)	(5,022,000)	(1,750,000)
65 & over					
None	31.4%	70.1%	67.8%	81.1%	95.6%
Partial	34.8	23.8	25.1	14.8	3.5
Major	33.8	6.1	7.1	4.1	0.9
No. of cases	(328,000)	(1,514,000)	(2,183,000)	(3,898,000)	(2,520,000)

Source: U.S. National Health Survey. Older persons, selected health characteristics, United States, July 1957--June 1959. Washington, 1960.

Table V

Mode of Travel Reported in Two Surveys of the Blind

Mode	Dog Guide Study (1957) Primary Mode of Travel	Dog Guide Study (1957) Primary & Secondary Modes of Travel	AFB Leisure Activities Study (1961) Primary & Secondary Modes of Travel
Travel unaided	42%	35%	27%
Sighted person	32	41	32
Cane	19	20	38
Dog	6	4	1
Other	1	--	2
Base	(500) respondents	(735) modes of travel	(766) modes of travel

Note: The first column shows the distribution of primary modes of travel in a sample of 500 blind persons age 15 to 54 in New York State and reported in Samuel Finestone, Irving F. Lukoff and Martin Whiteman, The Demand for Dog Guides, New York, 1960. The second and third columns show the distribution of primary and secondary modes of travel (many blind persons use more than one) percentaged on a base of all travel modes reported for each group. Data in the third column, which are preliminary, come from a sample survey of blind persons 20 years of age and above in four states. In view of this and other differences between the sample populations, caution should be used in making comparisons between them.

Table VI

Correlates of Mobility from the Dog Guide Study

Travel Mode by Vision Categories (Self-ratings)

	Totally Blind	Light Perception	Moving Objects	Recognize People	Able to Read
Travel without aid	8%	8%	22%	53%	86%
Travel with aid	92	92	78	47	14
No. of cases	(117)	(73)	(72)	(74)	(162)

Travel Mode by Travel Vision (Self-ratings)

	None	Slight to Moderate	Good
Travel without aid	9%	38%	84%
Travel with aid	91	62	16
No. of cases	(222)	(88)	(188)

Travel Mode by General Health

	Excellent	Good	Fair or Poor
Travel without aid	47%	39%	31%
Travel with aid	53	61	69
No. of cases	(280)	(117)	(99)

Travel Mode by Hearing Difficulties

	No Difficulty	Some Difficulty
Travel without aid	43%	36%
Travel with aid	57	64
No. of cases	(424)	(69)

Note: The source for these figures is Samuel Finestone, Irving F. Lukoff, and Martin Whiteman, The Demand for Dog Guides, New York, 1960.

Table VII

Mode of travel by Travel Vision

Travel Vision (Self-ratings)

Travel Mode	None	Fair	Good
Cane	57.4%	49.6%	23.5%
Sighted person	48.5	37.9	20.9
Travel unaided	5.4	26.3	57.0
Guide dog	3.4	--	--
Other mode	2.5	1.8	3.5
Don't go outside	5.3	2.2	2.6
Number of cases	(204)	(224)	(230)

Note: Persons with no travel vision are here defined as those who reported themselves totally blind or who have no more than light perception; those with fair travel vision have more than light perception but cannot recognize people they know if they are close enough; and those with good travel vision are defined as able to recognize people. Figures add up to more than 100% because some respondents use more than one mode of travel. Data, which are preliminary, come from the four-state AFB Leisure Activities Study made in 1961.

Table VIII

Mode of Travel by Age

	Age					
	All ages	21-39	40-59	60-69	70-79	80 & over
Travel mode						
Cane	41.1%	43.5%	32.7%	40.5%	43.7%	47.6%
Sighted person	35.4	24.3	33.9	39.7	42.4	34.7
Travel unaided	30.6	39.1	36.3	28.6	25.8	22.6
Guide dog	1.0	1.7	1.2	.8	1.3	--
Other mode	2.5	1.7	.6	3.2	2.6	4.8
Don't go outside	3.4	1.7	--	2.4	3.3	10.5
Number of cases	(684)	(115)	(168)	(126)	(151)	(124)

Note: Figures add up to more than 100% because some respondents use more than one mode of travel. Source of data: AFB Leisure Activities Study (preliminary).

Table IX

Mode of Travel by Education

	Education		
	Grammar School	High School	College
Travel mode			
Cane	41.2%	43.1%	44.3%
Sighted person	35.9	36.2	32.9
Travel unaided	31.6	28.9	31.4
Guide dog	0.3	2.3	0.7
Other mode	0.9	2.3	6.4
Don't go outside	3.4	3.2	3.6
Number of cases	(323)	(218)	(140)

Note: Those listed as having a grammar school education include persons who have had no schooling, others who have had some grammar schooling, and persons who never went beyond grammar school. Those listed as having a high school education include persons who have had some high school as well as others who did not go beyond high school. The college educated here include persons who have had some college, those who have finished college, and those who have gone beyond to take graduate work. Figures add up to more than 100% because some respondents use more than one mode of travel. Source of data: AFB Leisure Activities Study (preliminary).

Table X

Mode of Travel by Employment

	Employment Status	
	Employed	Not Employed
Travel mode		
Cane	45.9%	41.5%
Sighted person	22.0	39.4
Travel unaided	39.6	27.8
Guide dog	1.9	0.8
Other mode	0.6	3.0
Don't go outside	1.3	4.0
Number of cases	(159)	(525)

Source: AFB Leisure Activities Study (preliminary). Figures add up to more than 100% because some respondents use more than one mode of travel.

Table XI

Mode of Travel by Physical Condition

Travel mode	Respondents with other chronic conditions	Respondents with no other chronic conditions
Cane	44.1%	39.7%
Sighted person	37.9	31.0
Travel unaided	25.8	38.8
Guide dog	.7	1.7
Other mode	3.9	--
Don't go outside	4.6	1.2
Number of cases	(438)	(242)

Note: Respondents with other chronic conditions are those who answered "Yes" to the question, "At the present time do you have any other ailments or conditions that have continued for a long time, even though they don't bother you all the time?" Figures add up to more than 100% because some respondents use more than one mode of travel. Source: AFB Leisure Activities Study (Preliminary).

Table XII

Activity by Travel Vision

	Travel Vision (Self-ratings)		
	None	Fair	Good
Activity Score			
Least active (0-2)	32.4%	31.3%	23.5%
Next to lowest (3-4)	27.0	33.9	37.8
Next to highest (5-6)	26.0	21.4	19.6
Most active (7-10)	14.7	13.4	19.1
Number of cases	(204)	(224)	(230)

Note: In constructing the activity score different weights were assigned to different activities, as follows:

Activity	Weight
Attended movies in past 12 months	1
Get together with friends less often than once a week	1
Visit organizations or attend meetings once in a while	1
Go into stores to do shopping	1
Get together with friends once or twice a week	2
Visit organizations or attend meetings regularly	2
Get together with friends three or more times a week	3
Employed	3
Highest possible score	14

For definition of travel vision see Table VII. Source: AFB Leisure Activities Study (Preliminary).

Table XIII

Activity by Age

	Age					
	All ages	21-39	40-59	60-69	70-79	80 & over
Activity Score						
Least active (0-2)	28.8%	10.4%	16.7%	24.6%	37.7%	55.6%
Next to lowest (3-4)	33.0	20.0	34.5	38.9	36.4	33.1
Next to highest (5-6)	22.2	32.2	22.6	24.6	22.5	9.7
Most active (7-10)	15.9	37.4	26.2	11.9	3.3	1.6
Number of cases	(684)	(115)	(168)	(126)	(151)	(124)

Source: AFB Leisure Activities Study (Preliminary).

Table XIV

Activity by Education

	Grammar	High School	College
Activity Score			
Least active (0-2)	37.8%	22.9%	17.9%
Next to lowest (3-4)	35.3	32.1	28.6
Next to highest (5-6)	18.9	26.6	23.6
Most active (7-10)	8.0	18.3	30.0
Number of cases	(323)	(218)	(140)

Note: For definition of educational groups see Table IX. Source: AFB Leisure Activities Study (Preliminary).

Table XV

Activity by Income

	Income			
	Under $1000	$1000-1999	$2000-3999	$4000 & over
Activity Score				
Least active (0-2)	41.7%	27.9%	19.5%	13.4%
Next to lowest (3-4)	40.0	41.5	26.3	21.6
Next to highest (5-6)	12.2	19.0	33.1	30.6
Most active (7-10)	4.2	11.6	21.2	34.3
Number of cases	(120)	(147)	(118)	(134)

Note: Income here represents the amount received by the respondent and other members of his or her household in 1960. Source: AFB Leisure Activities Study (Preliminary).

Table XVI

Activity by Physical Condition

	Condition	
	Respondents with other chronic conditions	Respondents with no other chronic conditions
Activity Score		
Least active (0-2)	33.1%	20.7%
Next to lowest (3-4)	37.9	24.8
Next to highest (5-6)	19.4	27.3
Most active (7-10)	9.6	27.3
Number of cases	(438)	(242)

Note: For discussion of "other chronic conditions" see Table XI. Source: AFB Leisure Activities Study (Preliminary).

Table XVII

Activity by Attitude Toward Blindness

Activity Score	Consider self blind	Do not consider self blind
Least active (0-2)	29.5%	28.0%
Next to lowest (3-4)	29.2	37.0
Next to highest (5-6)	23.8	20.5
Most active (7-10)	17.5	14.5
Number of cases	(319)	(346)

Note: Respondents were asked: "Some people who can see to some extent consider themselves blind, and others don't. Do you consider yourself blind, or not?" Source: AFB Leisure Activities Study (Preliminary).

Table XVIII

Activity by Travel Training

Activity Score	Received travel training or help	Received no travel training or help
Least active (0-2)	12.0%	31.6%
Next to lowest (3-4)	31.0	33.2
Next to highest (5-6)	34.0	20.6
Most active (7-10)	23.0	14.6
Number of cases	(100)	(569)

Note: Respondents were asked if they had received travel training or help in traveling from public or private agencies serving blind persons. Source: AFB Leisure Activities Study (Preliminary).

Table XIX

Mode of Travel by Sex

Travel Mode	Sex: Male	Sex: Female
Cane	47.7%	37.5%
Sighted person	23.9	46.4
Travel unaided	35.5	25.8
Guide dog	0.9	1.1
Other mode	2.7	2.3
Don't go outside	2.4	4.3
Number of cases	(335)	(349)

Note: Figures add up to more than 100% because some respondents use more than one mode of travel. Source: AFB Leisure Activities Study (Preliminary).

Dr. Josephson summed up by saying that while a large number of blind people are interested in improving their mobility capabilities, only about one-third are active in a social sense, traveling up to physical capacity. The sizable minority not traveling up to physical capacity are the ones requiring attention in the future.

Dr. Murphy said that the group of statistics presented showed that there certainly is a problem with older groups, but he also noted that there are significant numbers of younger people not traveling to capacity, not earning as much as they might, and not enjoying as much social activity as one would like to see them have.

Dr. Murphy then called on Mr. Russell Williams to tell about the Veterans Administration program.

The VA program in which mobility procedures have a part started years ago in domiciliary facilities. After World War II, Mr. Warren Bledsoe made a survey of this work in domiciliaries. The mobility training under these circumstances is slower paced and does not generally reach the levels attained in programs often described as mobility training programs. The domiciliary programs are good, but are adjusted to the needs of the 60 - 85 year age group found in these centers. There are about 25 blind veterans at Bay Pines, Florida, 40 at Kecoughtan, Virginia, 30 at Bath, New York, 35 at Milwaukee, and 60 or so at Los Angeles. There are also such supporting programs at Bronx, New York, and Tuskeegee, Alabama. It should be made clear these facilities are not places for a blinded veteran to get mobility training per se. Such training is given at these centers in support of their program looking to the general well-being of their members.

The first rehabilitation center for the blind veterans of which Mr. Williams had any information was established in Paris, France around the year 1250. It housed some 300 men blinded in the crusades. After World War I England established St. Dunstan's home for blinded veterans which is still active today. Canada established a center, as did the United States near Baltimore. This latter program continued into the Nineteen-Twenties.

The United States instituted such programs during World War II through the Departments of the Army and Navy. In late 1947 the Veterans Administration was directed by Presidential order to provide this type of personal and social rehabilitation for blinded veterans. The Veterans Administration then established at Hines, Illinois, one of its 170 hospitals, a center where such rehabilitation and research into the problems of blindness could be carried out. At the present time approximately 80 veterans go each year to Hines for this program. The patient load at the facility approaches about 30 at any one time, and the applications for admission are higher today than at any time in the past.

During World War II it was decided that although the segregation of blinded veterans would be in general undesirable, a short period of segregated training was essential. Four months seems to be an appropriate length of time for such a training program. At present 62% of the trainees at Hines have some other handicapping condition. The age range is 18 to 79. Mr. Williams emphasized that although Hines has become known as an orientation and mobility center, in fact these are only elements of the total program for rehabilitation, not more important than braille and communication techniques, manual skill development, personal and social counselling. The second half of the 30 minute version of the film "The Long Cane" was then shown to the group.

Dr. Murphy then called on Mr. Robert H. Whitstock of The Seeing Eye, Inc. to tell about the dog guide. Mr. Whitstock pointed out that at present there are two validated techniques that enable the blind person to get around independently, the long cane method as taught at Hines Hospital, and the dog guide technique as pioneered at The Seeing Eye, Incorporated. Not many blind people use either of these means and effort should be made to motivate people to use the existing methods as well as to develop new methods usable by the blind.

The dog guide methods originated in Germany after World War I. In 1928, after this work was described in a magazine article, a dog obtained from Switzerland was tried all over the United States under varying conditions. The result was that The Seeing Eye organization was founded in 1929. Since then over 2700 individual blind persons have been furnished with some 4000 dogs. In the early 1940's a breeding farm was established where scientific principles have been applied to develop an increasingly effective Seeing Eye dog in terms of size, temperament, adaptability, health, etc. Mr. Whitstock then briefly touched on the membership mode of funding used at Seeing Eye and the success of this approach. The name "Seeing Eye" has been registered and refers only to dogs trained at the Morristown, New Jersey School. The generic term for a dog that leads a blind person is dog guide.

In the mid-1950's The Seeing Eye asked the New York School of Social Work to conduct a study, a kind of market analysis, of the problems of mobility of the blind and the relationship to dog guides. With the Office of Vocational Rehabilitation, Seeing Eye is currently making a joint study to determine just what the public attitudes toward blindness really are. Grants on medical and veterinary projects have also been made.

Mr. Whitstock then touched on some highlights of The Seeing Eye program. The training course at Morristown is four weeks long. The large numbers of elderly blind people often do not have the physical stamina necessary for working with a dog. The environment at The Seeing Eye is purposely controlled to achieve the maximum benefits for the trainees during their stay at the school. The schoo also attempts to provide some individual training in personal grooming, table etiquette, and information on possible future employment.

The Seeing Eye makes a charge of $150 to the blind person for providing a dog and giving the four weeks training. A charge of $50 is made in case of replacement of a dog, usually after 8 to 10 years of service. This charge, paid by the blind person himself, is for a number of reasons considered an essential element of the program. Mr. Whitstock then showed an interesting color movie about Seeing Eye dogs. The film produced "from the point of view of the dog", was very informative of the whole subject of dog guides.

Mr. Whitstock then answered some questions from the audience. Dogs must be fed once or twice daily and the cost of maintenance is $10 - $15 per month. The dogs should be brushed and combed daily and should be given daily obedience exercises. For biological needs the dogs should be "aired" four times a day at relatively regular intervals. Problems with restaurants, hotels, and public transportation systems are no longer frequent. Statistics indicate that dogs are an asset rather than a liability as regards employment of blind persons.

Mr. Whitstock then developed the concepts of guidance as they relate to dog guides. The dog uses his vision, hearing and sense of smell. He reacts selectively to the information coming from these sensors, filtering out information irrelevant to the navigational problem at hand. Essentials like curbs, steps, overhanging obstructions, people, moving cars, are noted and reacted to. The master receives his information through the U-shaped harness he holds in his hand. The dog stops at curbs, thus signalling their presence to the master. If given the command "forward" the dog will step off only if conditions are safe. The dog pauses momentarily at shops or other places frequently visited, enabling the master to decide whether to enter or proceed further.

Dr. Pollack asked about simultaneous use of a dog and cane. Mr. Whitstock said this was not advantageous because the dog alone avoids obstacles and having a hand free to carry something other than a cane is important. In some cases, such as attending a dance, it may be best not to use a dog guide, but to rely on a cane and the sighted assistance usually available on such occasions.

Mr. Mauch said he has often thought of the problem of designing a device that would perform as well as a dog and that he finds the difficulties staggering. He wondered why the percentage of blind people using dogs was so small. Mr. Whitstock replied citing some of the many reasons: of the legally blind over 50% are over 60 years old, often unable to work physically with a dog; 70% have some residual vision and persons with some travel vision seem unable to work effectively with a dog; 10% are below the age set by Seeing Eye as a minimum for responsible training and the handling of a dog; some are mentally retarded, and have other complicating handicaps like deafness, heart disease, or disorders of the central nervous system that interfere with balance and coordination.

A recent "market analysis" type of study by the New York School of Social Work showed that less than 2% of the legally blind are physically, mentally, and emotionally qualified to use dog guides and that less than 1% use them now.

Dr. Josephson asked whether there were any uniform standards of operation for the several dog guide schools throughout the country. Mr. Whitstock said standards varied, that 3 or 4 of the largest schools could probably handle the work load, but that there are probably 11 schools in existence. He said that sometimes personnel who leave The Seeing Eye carry some of its ideas to other schools. Dr. Josephson inquired as to the communications existing between the several large schools. Apparently such communications need further development. Mr. Donald Kauth of Guiding Eyes for the Blind said he felt his organization was very close to The Seeing Eye in many respects. Their director was at The Seeing Eye for many years and they too believe strongly that a fee should be paid by the blind person himself.

Mr. Holopigian then asked Mr. Williams about an ideal cane, one that was collapsible, light, strong, and had the proper resonance. Mr. Williams said people at MIT are interested in producing a design for a better cane. He had discussed this only the previous evening with Professors Mann and Baumann. Mr. Williams said length is a very important aspect of a cane. He himself, because of the contingencies of extensive travel uses a cane of greater length than most. It would be wonderful if one could vary the length for particular circumstances, retaining all necessary qualities of a good cane. He felt that 50% of the weight of the cane should be in the upper third and that the diameter at the crook should be about 7/8 inch. A rubber core tip seems to absorb certain bits of information the user needs and some ferrules have acted like a pendulum, a case of too much weight at the tip. Professor Benham asked about a cane with a 3/4 inch rubber section near the tip introduced to facilitate gliding over rough spots in the road. Mr. Williams had used one of these and found difficulty in telling the difference between grass and a mud puddle with such a cane. Professor Benham then raised the old question of a wheel on the end of the cane. Mr. Williams said most he had seen or heard about were too heavy, with too much lost motion, but that he would not necessarily take a stand against wheels. Dr. Murphy asked about caster-like wheels, another common suggestion, and Mr. Williams said they have too much lost motion and make it difficult to know what the cane is going after. Mr. Williams agreed with Professor Benham that there is a psychological block against wheels on canes. Mr. Freiberger said canes with wheels might not be good for the occasional use as a support to catch one from stumbling. Mr. Williams agreed that the cane served to identify a person as blind to the sighted community and that this is not an unimportant function. There was then a brief discussion of aid from sighted passersby.

Mr. Williams said it was part of general rehabilitation training to teach a blind person how to shift gracefully from a position where his arm is grasped by the guide who tends to push and shove to the position where the blind person places his hand on the back of the sighted person's arm.

Mr. Kauth said all present were undoubtedly interested in mobility and its motivation, but that he was concerned that of the 11 dog guide schools, of which 8 are training actively, representatives of only two such organizations were present at this meeting. Dr. Murphy said that he planned the sessions on dog guides and the cane to serve as background for the electronic instrumentation contingent not as exhaustive discussions of these travel aids. Mr. Kauth said he was only making a plea for more communication between the several dog guide organizations. Dr. Hoskins said somewhat similar problems have long been known in medicine and Dr. Murphy said that the efforts of the American Foundation for the Blind to establish general standards for agencies dealing with the blind were certainly in the right direction.

There was a question from a cane technique instructor about the problem of "airing" the dog guides frequently throughout the day. Mr. Whitstock pointed out that most difficulties could be overcome by correct training and were not results of dog guide use per se, but rather poor or misunderstood training. Under almost all conditions, with use of some common sense and proper training of the dog, "airing" should take but a few minutes and need not be a problem. Mr. Kauth told of a simulated curb at Guiding Eyes for the Blind where dogs are taught the process of being "curbed" without the presence of grass or gravel or earth.

The group then adjourned for lunch.

CONCURRENT SESSION B- AFTERNOON SESSION
THURSDAY, OCTOBER 12, 1961, BUSH ROOM

Dr. Murphy called on Professor Benham to give a review of the whole field of experimental mobility devices. Professor Benham felt that many of those present knew the story, so he decided to be brief and then to answer specific questions. The VA asked Haverford-Biophysical Electronics to file a patent application on their work and the search of patents turned up some things of interest. The first patented electronic guidance device the searchers found was patented in 1931. Thus work on electronic aids goes back some years, but not as far back as the cane, which, next to the human guide, must have been the first guidance system used in antiquity. This 1931 Vision Tone Device, U. S. Patent No. 1,820,357 issued to L.O.B. Lindstrom et al was in the shape of a pair of spectacles with photo-sensitive materials in the eye positions controlling the frequency of an oscillator whose tone was fed to the ear through an ear-piece. The electronics of 1929 (the filing date) and earlier was bulky and crude by today's standards. Perhaps using modern techniques such as are so successful in hearing aid design one could build a useful head-mounted unit worn like spectacles. There was an electronic cane in these early days too, a precursor of the Franklin Institute cane. In 1944 J. B. Walker filed on a Photoelectric Range Finder and U. S. Patent 2,444,235 was issued to him June 29, 1948. None of these schemes seemed to gain any wide acceptance. In 1945 Stromberg-Carlson did work under the CSD program on ultrasonic guidance devices for the blind. There were problems, at that time anyway, of generating enough energy at sufficiently high frequency that surfaces would reflect enough back to the receiver. Specular reflection is not satisfactory for this application. The normal turbulence of the air also interfered with the transmission and reflection paths, giving rise to spurious indications. Professor Benham recalls standing still with one of the devices watching a tree "come and go" even though he knew it was quite stationary. These difficulties with ultra-sonics suggested that attention should be shifted to the shorter wavelengths of visible or near infra-red light; energy whose reflection from most surfaces (except mirrors) is sufficient to hope for reasonable detection capability in spite of scatter.

It is apparent that sensitive receivers are a necessity in these mobility aids for the blind. For sonic systems the human ear would seem to be an excellent receiver. It is used by most blind people in just this way to listen to echoes from objects in the environment. It would be best not to encumber the ear with any device which might impair its natural abilities. There was some thought about sending out a sonic beam, the reflection of which could be picked up by the ear. This was not found too successful by Dr. Clifford M. Witcher, a blind physicist, who tried such schemes several years ago. His untimely death in 1956 was assuredly a setback in the field of electronic mobility devices for the blind. He had built a 10 kc pulsed sound projector which looked something like a flashlight with a large end.

One could hear echoes from objects, but the everpresent echo from the floor tended to obscure them. Professor Benham tried the device over a period of time, but found it of little practical value. He told of the use of reflected sounds from the footsteps of the blind person, a good system, but only under ideal conditions. When walking on a soft rug or grass or in a very noisy area, such weak sounds are easily masked. Attempts to increase the signal-to-noise ratio by snapping a toy "cricket" in the hand were in the right direction, but the information gained never seemed to justify the method. Perhaps fresh ideas along these lines would be worthwhile. Professor Benham then referred to the work of Professor Karl Dallenbach and his associates who studied the "mysterious" ability of some blind people to detect obstacles (See: M. Supa, M. Cotzin, and K. M. Dallenbach," 'Facial Vision' - The Perception of Obstacles by the Blind," Amer. J. Psych., Vol 57, pp. 133-183, 1944, P. Worchel, and K.M. Dallenbach, " 'Facial Vision' : Perception of Obstacles by the Deaf - Blind, " Amer. J. Psych., Vol 60, pp. 502-553, October 1947; M. Cotzin, and K.M. Dallenbach, " 'Facial Vision:':The Role of Pitch and Loudness in the Perception of Obstacles by the Blind," Amer. J. Psych., Vol. 63, . No. 4, pp. 485-515, October 1950). Dallenbach concluded that hearing was the chief basis of "facial vision."

One must remember that hearing acuity, especially for the important, higher frequency sounds, deteriorates with increasing age. This poses an obvious problem to aging blind people who have used their hearing to advantage as an aid to mobility.

Professor Benham said that the use in the 1940's of artificial sound sources as aids to the ear in detecting obstacles never proved valuable enough to warrant production.

The Signal Corps Sensory Aid developed by Dr. Lawrence Cranberg was then mentioned as the first electronic guidance device which showed promise of being practical. RCA built 25 of these units, and an evaluation was performed by Haverford College with Professor Benham as principal investigator (Thomas A. Benham, "Evaluation of Signal Corps Sensory Aid for the Blind, AN/PVQ-2 (XE-2), report on VA Contract V1001M-1900, April 25, 1952). Several improvements were suggested in the report of this study.

Professor Benham then described the pencil-like probes of light or infra-red energy that characterize both the Signal Corps device and the one he later developed under contract to the VA. Users must learn to sweep this beam over a path width of about 3 feet, 8 or 10 feet ahead of them, centered on their direction of travel. There was then a brief discussion of automatic scanning and the limitations of a pulsed system in scanning for obstacles; all very reminiscent of the radar problem.

Curb detection is a more difficult problem. The only thing unique about curbs is the change in level. The Franklin Institute cane will detect this change. Professor Benham personally feels that the advantages of this cane over an ordinary one are not sufficient to justify the added cost and complications in use. A greater degree of early warning than is provided by either the regular or FI cane would be very helpful. This need for earlier warning is met by devices using a beam of light. The Signal Corps device was a satisfactory, indeed sophisticated, obstacle detector for its time but was of questionable value as a curb detector. Only a few users were able to sense the subtle change in its continuous signal indicating a curb.

Professor Benham then spoke of economic factors, saying he did not think it desirable to market a device that would be useful only to a very few blind people; they could probably do as well with a cane or a dog. What is needed is a simple device, moderately priced, good enough that it can be proven worth its cost.

The speaker then demonstrated the Signal Corps device, reiterating how well it performed as an obstacle detector, but saying he could not use it at all as a curb finder. Movement of the hand-held instrument was cited as a difficulty and stable platforms were suggested as a possible solution, but these are complex and require considerable operating power and space. Dr. Murphy illustrated the geometry of the problem by a sketch showing how hand swing caused an apparent change in range which could be mistaken for a curb. Dr. Greening suggested response to the second derivative of range rather than the first derivative as the curb indicator. Dr. Murphy acknowledged this as one of the more subtle suggestions that often came up.

Professor Benham then mentioned passive devices and cited Optar as an example (H. E. Kallmann,"Optar, A Method of Optical Automatic Ranging as Applied to a Guidance Device for the Blind", Proc. IRE, Vol. 42, No. 9, pp. 1438 - 1446, September, 1954). This device scanned the surround with a lens system and then explored the image space in depth with an interposed, spiral-formed, rotating, coded, interrupting disc. The light passing through the disc fell on a photocell and the audio output from the device was indicative of the existence and range of objects in the field by virtue of the optical contrast usually associated with them. Professor Benham said that the device when tried several years ago did not seem to supply enough information to a blind person to make it worthwhile. He thought further development might lead to something better. Mr. Holopigian said he had recently seen an ambient light device being developed by Dr. Bertil Jacobson in Sweden which would have a tactile rather than audible output.

Dr. Murphy then mentioned a suggestion made by Professor Norbert Wiener of MIT involving a pair of photodevices mounted on a bar. Their convergence was controlled by the user through squeezing the pistol type handle while wrist flexion allowed scanning. An audio output was to be generated from the two optical probes by differentiation of the light intensity and when converged to the correct degree the same signal would come from both simultaneously if optical contrast existed at the point of intersection of the lines of sight of the devices. The presence, direction, and range of the object would thus be indicated by the sound, direction and squeeze respectively. Dr. Murphy mentioned that Dr. Karl S. Lashley, a member of the original Committee on Sensory Devices, once suggested a somewhat similar plan by analogy to the "primitive eye" found in some animals.

Professor Benham mentioned that a Mr. Joseph Shaw had obtained a patent on direct stimulation of the cortex (Joseph D. Shaw, "Method and Means for Aiding the Blind", U. S. Patent 2,721,316, filed June 9, 1953, issued October 18, 1955). These methods have not yet been put into practice, and Professor Benham said that perhaps someday useful developments in this area would be forthcoming.

Mr. Freiberger then showed a series of slides he had prepared to illustrate some of the ideas Professor Benham had mentioned in his historical survey. Following is a list of the items shown, together with the date of the original document from which the slides were prepared:

1931 Vision tone device (Lindstrom)
1948 Signal Corps Sensory Aid (Cranberg)
1948 Stromberg Carlson ultrasonic device
1949 Optical Ranging Device (Cranberg)
1950 Cane with plunger air whistle (Richardt)
1950 Indicator for Blind (Walker)
1952 Signal Corps handle (Ulrich)
1952 Echo Ranging System (Meeker-Slaymaker)
1953 Sound Projectors (Twersky)
1954 Optar (Kallmann)
1955 Witcher's device
1956 Signal Corps infantry surveillance radar
1957 Cane (Barry)
1958 Cane, with rollers (Swidzinski)
1959 Franklin Institute cane (Frank)

Mr. Freiberger and Dr. Murphy provided some commentary which accompanied the showing of these slides. Dr. Murphy also put a diagram of the curb detection geometry on the blackboard.

Dr. Murphy then called on Dr. Don DeVault to tell about the curb detector work in progress at Haverford College- Biophysical Electronics (a division of Communication Industries, Inc.). Dr. DeVault, referring to Dr. Murphy's drawings on the blackboard, reiterated the difficulties of curb detection by change-of-range triangulation methods, especially considering the small base dimension and the small range change in the considerably larger total distance. He then mentioned Dr. Witcher's work on a guidance device at MIT, describing the automatic scanning system whose complete development was prevented by Dr. Witcher's death.

The method of Haverford-Biophysical Electronics was then described. A pulsed light is projected out to the ground ahead of the unit, and an image of the illuminated spot on the ground is formed on a photocell matrix, which is positioned by a servosystem so as to center on the image at all times. The position of the photocells is then a measure of the range to the ground, and the first or second derivative of the position of the photocell carriage as it tends to follow the image spot will be related to derivatives of the range. One could expect prominent signals from these derivatives on sudden change of range as, for example, when the projected spot passes over a down-curb. To realize this effect in practice, it was first thought necessary to stabilize the instrument against the motions of the user. This was done by a pendulous type mounting, of long period, which tended to smooth and slow the oscillations caused by bodily motions. The device was tried about a year ago and worked fairly well, but better when clamped than when free to swing.

It was found that down-curbs were detected primarily by a "hide and seek" principle rather than by response to range shifts. A small spot of light projected from the upper lens of the instrument is always viewed by the lower, except when hidden behind a down-curb. This complete loss of return signal is the phenomenon signalling a curb. Raised obstacles can be detected by a limit setting on the servo travel so that as the spot rises on a wall, for example, the follower will go just so far, strike its stop and signal that there is an obstacle.

Dr. DeVault then mentioned a possible design utilizing a cane-type device with an energy source high up, a receiver midway down the cane to detect down - curbs by the "hide and seek" principle and a second receiver near ground level to respond to energy reflected back from vertical surfaces like up-curbs or obstacles. Preliminary measurements indicate such a system has promise. Dr. DeVault then pointed out that Biophysical Electronics was currently concentrating on building some improved obstacle detectors. Components used in these units may very well be usable in a curb detecting device having a cane form such as mentioned above.

Mr. Zito of Bendix Corporation asked what advantage the "hide and seek" cane would have over an ordinary long cane. Dr. DeVault replied that the electronic cane would be held vertically, without the need to probe out in front. There would be no risk of tripping other people. Also, the device would detect curbs and obstacles at longer range than the ordinary long cane ,thus providing an early warning feature.

There was then a brief discussion between Professor Baumann of MIT and Dr. DeVault relating to the most efficient light sources and detectors. A lamp recently obtained from Edgerton, Germeshausen & Grier, Inc., seems considerably better than sources used previously. The detector currently favored by Dr. DeVault is a Hoffman Electronics silicon PN junction miniature solar cell.

After a short recess, Mr. Freiberger read some material on the Franklin Institute cane supplied by Mr. Robert J. Gibson, an engineer at Franklin Institute, who could not be present.

Mr. Freiberger said the work on the Franklin Institute Electronic Cane was supported by the W. K. Kellogg Foundation, and by the Office of Vocational Rehabilitation of the Department of Health, Education and Welfare. Paraphrasing Mr. Gibson's notes, Mr. Freiberger continued:

The builders believed that there are four elements useful as guideposts in the development of an electronic travel aid.

First, the ordinary cane - a simple extension of the arm - is still a most successful and popular guidance device.

Second, the greatest number of travelers can absorb and use only a single piece of extra guidance information. This was chosen to be the detection of a step-down.

Third, the user needs a warning stimulus only when, and for as long as, the step-down hazard threatens him. A single strong stimulus, warning of danger, is usually met immediately with the appropriate avoidance reaction while other environmental cues are still available.

Fourth, a travel aid must be "fail-safe". In this instrument the cane is still a cane and can be used as such.

CONFIGURATION

The cane is constructed with a hollow tapered shaft approximately three feet long, made of glass fiber bonded with plastic. At the end of the shaft there is a replaceable hardened metal tip. The handle, placed at an angle to the shaft, is made of impact-resistant plastic and contains all of the electronic equipment. At the forward end of the handle is a small knob for tuning the circuits for the height at which the

tip of the cane will normally be carried. At the rear is a second knob for on-off - volume control. The cane is gripped with the handle held horizontally. A small plastic stimulator protrudes slightly from the right side of the handle. When the tip of the cane passes across the edge of a step-down, this button signals the user by vibrating strongly against his hand. In addition to this signal, the circuits generate, if desired, a whistle that can be heard in an earpiece connected to the cane handle by a flexible lead.

USE

The chief advantage of the electronic cane is that it sweeps a zone continuously in the path of the traveler, while a tapping stick only samples small bits of the path at the point where the tip touches. Tapping is unnecessary.

The electronic cane will give a stop signal whenever the tip passes over a down step, curb or a hole; the shaft should then be used to probe the depression in normal fashion. Electronic detection is thus combined with the basic attributes of a cane to give a travel aid which is superior to either.

The cane balances nicely and its shaft assumes a natural position across the body and at the proper angle to the ground. The level sweeping motion required is easily learned. Though the electronic cane is heavier than a wooden cane, its balance and large comfortable handle make it easy to carry.

With a little practice, the best height for the set-point will be found; two inches is about the average. At this height, there is some leeway for rises and dips during the sweep. Tuning soon becomes second nature to the user. At any time during a walk, the user can reassure himself that the cane is operating properly simply by lifting the tip for a moment to see if the signal is given.

The response of the cane to a drop-off is very quick. Normally, the tip of the cane will have passed over the drop-off by only a few inches when the stop signal occurs.

CIRCUITRY

The electronic cane is essentially a proximity device, capable of detecting that its tip is at a distance greater than two inches from any grounded surface including asphalt, concrete, sand or wooden boards on the ground. Its circuit contains two oscillators.

As the distance between metal cane tip and ground increases, the capacitance of one oscillator circuit decreases, thereby changing its frequency. The two oscillators, operating at approximately two megacycles, are beat against one another, and "locked-in" sufficiently to provide a sharp onset of any difference signal. A difference signal occurs when the ground falls away from the tip.

Detected by a diode detector and amplified, this difference signal provides the audible signal heard in the earpiece. Further amplified and smoothed, it operates a small motor which in turn drives an eccentric that is attached to the plastic pin that gives the tactile stimulus.

A built-in 110 volt charging circuit with separate line cord will recharge the 10.8 volt nickel cadmium cell overnight, storing enough power for over a full day's use by an experienced traveler. The current drain on the battery is less than 8 milliamperes with the motor not operating, rising to between 100 to 200 milliamperes with the motor on (one to five seconds usually).

DESIGN FACTORS

Early in the development of the cane it was realized that an auditory stimulus might interfere with other auditory cues. It was necessary to provide a tactile stimulus for three reasons: first, because of the acoustic shielding of the ear by the earpiece; second, because many blind people objected to the inconvenience and appearance of an earpiece; and last to provide a stimulus which would not be masked by heavy traffic noises.

A tactile stimulus had to be produced that would always be noticed, even through gloves, and that would not require careful or fixed placement of the hand. A small motor with eccentric pin (5/32 inch diameter with rounded end) giving a 3/32 inch maximum stroke from a small hole in the side of the handle was found to be quite suitable. The motor uses from 0.5 to 1.5 watts for a few seconds depending on how tightly the hand is pressed against the pin. A good stimulus is obtained even with a strong grip and on any part of the hand which touches the pin.

The acoustic signal was retained as optional because of its value to the instructor in the training program.

Another factor in the design was the stability of the set-point of detection. While the set-point could be reset at any time, drift could be both a nuisance as well as dangerous. For some time temperature change was a source of drift of the set-point. Temperature stability was finally achieved by making the two oscillators identical including the cables down the shaft. Weather conditions have little effect on the set-point; wet pavement, drizzle, or snow has little or no effect on the tuning point.

Rugged materials are used throughout the cane. Light-weight plastic-bonded Fiberglas hollow shafts have proved almost indestructible.

The present electronic cane weighs just two pounds but was designed with the center of gravity below and approximately in the center of the hand. Thus no torque is required to hold it in position and very little fatigue results.

TRAINING PROGRAM

It is easy to learn to use the cane. In teaching over 50 trainees it has been found that over 80% can learn to travel safely with it in less than five half-hour sessions. On the average, about two weeks practice with minimum supervision and a final checkout with an instructor complete the training program. In order to perform a large scale evaluation program 100 canes have been produced. The evaluation program will enable development of a complete training practice procedure.

Mr. Holopigian asked whether the evaluation of the 100 canes had commenced. Mr. Freiberger and Dr. Murphy were uncertain but told something about the construction of the units by Stromberg Carlson and of plans for evaluation by state agencies for the blind. There was then some discussion of the four guidepost elements brought up in Mr. Gibson's notes, and exception was taken with the thought that blind travelers can absorb and use only a single piece of extra guidance information. Mr. Mauch thought a cane having all the attributes of the proven long cane and also fitted with the Franklin Institute sensitive tip should be an excellent device. The only disadvantages Professor Benham could see in this were the added weight and added cost. Dr. DeVault and Mr. Williams had tried the cane and noted that in passing over a curb the tip had to get almost 6 inches out before the signal was given even though the ordinary ground setting was for about 2 inches. Considering the shortness of the cane, this was felt to be very short notice of the curb, and Professor Benham noted one would need very fast reactions to respond in time.

Dr. F. S. Cooper of Haskins Laboratories then told about the Committee on Sensory Devices. There was very little information on which the Committee could base its efforts, and the members had to start from scratch in most cases. Dr. Bush realized many of the problems would be on the human side rather than in engineering, and the Committee was oriented towards human engineering. It included medical people, physiologists, psychologists, and a physicist. The general problems undertaken were a guidance device and a reading machine. A comprehensive account of the Committee and its work may be found in the book, Blindness, Modern Approaches to the Unseen Environment edited by Paul A. Zahl and published in 1950 by the Princeton University Press. (Unfortunately, this excellent volume is out of print, but may be found in some libraries and specialized collections.) Haskins Laboratories served as central laboratory for the Committee.

In the guidance device area the main development effort was left to three principal contractors: Stromberg Carlson, Brush Development, and Hoover Vacuum Cleaner Co. The Committee decided that perhaps the supersonic type of active device deserved the most immediate attention, so all three contractors aimed at supersonic echo-ranging units. Hoover used a mechanically driven transducer, Stromberg Carlson a magneto-strictive type and Brush a crystal. The Stromberg Carlson units were developed to the point where they could get some field tests. At about the same time Cranberg developed an optical system in the Signal Corps. Arrangements were made to give the Stromberg Carlson and Signal Corps devices parallel tests by the same agency. Many such tests were conducted first with one device, then with the other under the same conditions.

At first, the Committee felt that a guidance device would have to provide the same kind of awareness of the spatial environment that a sighted person has. This concept was later modified and emphasis was placed on development of a short-range obstacle avoidance device rather than a complete guidance and orientation system. At first, range information on objects up to 50 feet away was thought necessary, but this was later reduced to much closer limits as discussed in a paper by Witcher (C. M. Witcher, "Some Communication Aspects of Visual Prosthesis," paper presented at meeting of the AAAS December 28, 1953). The blind subjects used in the experiments did not want such long range information to aid in their mobility, but rather were concerned with obstacles and pitfalls close at hand. Another conclusion in the early days was that point-by-point searching is not a good way to get information from which to make a construct of the surroundings. Dr. Cooper suggested scanning an unfamiliar environment through a soda straw to gain an appreciation of the difficulties of making a visual or mental construct of such surroundings by a point method. A third suggestion was that a device, even if only for obstacle avoidance, should help with orientation; for example, it should assist the user in walking a straight line.

Dr. Cooper then showed some lengths of motion picture film taken both by Stromberg Carlson and Haskins Laboratory. These films were prepared as laboratory tools rather than final productions. The pulse repetition rate of the Stromberg Carlson device illustrated was constant. The character of the return sound varied depending on environment. The tests were conducted on a course inside the laboratory and the instruments were also taken outside and used in the streets near the laboratories. The film also showed Witcher's 12 kilocycle sonic horn which Professor Benham had previously mentioned. The Signal Corps device was also shown in use in a section of the film. Dr. Cooper said there were about 18 or 19 devices tried during the CSD program. He said it was very difficult to rate the several devices used on the basis of the rather limited tests conducted. It appeared that inside the laboratory the Signal Corps device had a slight edge over the supersonic ones, the narrow beam giving better resolution, and specularity not being much of a problem. Outside, if either type were to have an edge, he thought it may have been the supersonic devices.

The optical device at that time was rather sensitive to ambient light, and the desired signal was buried in a hissy background out in the bright sunlight. Also, a rather confusing array of ranges was indicated when the device was pointed at a picket fence or a hedge. The only statement that could be clearly made about these devices at the time was that they showed about equal promise at equivalent levels of engineering development.

The maintenance problem also comes up with such devices both in laboratory tests and especially under non-laboratory conditions. Dr. Cooper spoke of the considerable frustration experienced by the workers at the frequent breakdowns of the equipment. Changes in signal presentation as the engineers tried to improve the device also bothered the evaluators. Theywere also troubled when one unit was in operating condition and another was not, both being scheduled for comparative tests at the same time and the same place.

Dr. Cooper then said that in development, there are two apparently contradictory requirements. On the one hand, it is urgent that design engineers produce devices as quickly as possible for the psychological testing program. On the other hand, careful engineering is required if the devices are to be reasonably reliable during the test.

Dr. Cooper feels that the CSD succeeded in teasing out some of the problems in this field. The difficulty was not so much in collecting information from the environment as in conveying it to the human quickly and easily and in a usable form. Another area of important information emanating from the work of the CSD was that they mapped out several attractive blind alleys that exist in this work. One hopes that other investigators will not try these alleys again. The devices used in the CSD study are perhaps out of date today, but some of the information developed from the psychological testing is not. It is still available and should not be ignored by future researchers.

Dr. Cooper then quoted something that Dr. George W. Corner, then Chairman of the Committee wrote in the book "Blindness," and we repeat this quotation: - "One thing has surely been gained....., which we hope will be plainly apparent to all who read this book. This is the realization by physicists, engineers, and mechanical inventors that when a machine is to act upon a man there are always going to be biological and psychological limitations that outweigh all the mechanical difficulties." Dr. Cooper stressed the importance of this concept for those who work with aids for the blind.

There was a general feeling of disappointment expressed that the active work of the Committee was stopped around 1947. Several devices had been developed, but they did not appear too useful so the program was cut back, probably because it was felt that useful devices could not be achieved within the next year or two. Dr. Cooper then summarized by saying: -

1. The problems are tough, perhaps tougher than anyone thought.
2. They are not insoluble and perhaps this is a statement of faith.
3. Once we have focused down on obstacle and curb detection alone, we must not forget that this is only the first objective; the real problem is giving a blind person an idea of the environment and not merely giving him a device which helps avoid bumping into something.

Professor Benham then mentioned the work of Mr. Nathan Sokal at MIT in the late Forties. Mr. Sokal developed a synthetic research device which presented an impression of the environment in raised pins, mosaic fashion, as the person traversed the environment. The conclusion from this work was that such a device would be useful, and Professor Benham then interjected that the problem is how to put this into practice. Professor Benham then raised the question of ultrasonic devices; he had, in a sense, belittled these yet Dr. Cooper had indicated that perhaps they were on a par with optical devices. Professor Benham said that the difficulties with the supersonic devices he had mentioned were the turbulence in the medium and generating high enough frequencies to provide sufficient reflection from obstacles. Dr. Cooper replied that neither the optical nor the supersonic methods were without faults and that the procedure to follow would be to balance off the inevitable disadvantages of each. He feels that specularity is the main disadvantage with supersonic systems. In real outdoor environment, the experimenters found that problems of specularity were not as serious as they were in laboratory situations.

Dr. Cooper said he felt it was still an open question as to which system would prove the better in devices developed to equivalent engineering levels. Dr. Murphy then said he thought the chief disadvantage of the ultrasonic method was that it showed considerably less promise than the optical methods with respect to the curb detection function. Dr. DeVault then inquired what it was about the supersonic guidance system used by bats that made it so successful compared with those developed by man for the use of the blind. Dr. Cooper replied jokingly, "A longer development period," and in all seriousness pointed out that the bats are able to listen directly to the returning echo of a sound they produce and to attribute that sound to the object out in space. When man uses the supersonic system, there is often the feeling that the echo sounds are originating in the ear phones if the system is of that type and perhaps there is some confusion between original sound and echo in the case of the hand-operated clicker.

Dr. Murphy then asked Professor Gibson, who had just arrived from another session, if he would give some comment on electrical vs. tactual stimulation. Professor Gibson said that brief current pulses of 1/2 to 1 millisecond duration were not discriminated well one from the other, but the sensation they produce is confined to the area of the body being stimulated. If several points on one limb

are stimulated, the localization is good, and the phenomenon (observed with mechanical stimulation) that the sensation sometimes comes from a place other than the point stimulated does not occur. If the correct body sites are chosen, electrical stimulation can be a reliable, painless method. If the stimulus pattern is only spaced in time, then individual pulses should not be closer together than 50 or 100 msec if many stimuli are to be used. Under certain conditions of stimulation it is possible to cause the pain threshold at a selected spot to rise, the touch (response to the electricity) remaining the same. This tends to strengthen the idea that the pain and touch systems are independent, and also points to the usefulness of this method of stimulation. Discussion on skin resistance and stimulation of hairy and non-hairy tissue followed. Professor Gibson said it took 2 to 2½ times the power to stimulate hairy areas as non-hairy. A more thorough presentation of Professor Gibson's ideas will be found in the section he himself prepared for Concurrent Session A, given Thursday Afternoon, October 12.

Dr. Murphy then introduced Mr. Alexander Roth of Ft. Walton Beach, Florida, who demonstrated his guidance device principles using a working model housed in ordinary mailing tubes (See: "Summary, Conference on Electronic Obstacle and Curb Detectors for the Blind," R & D Division, PSAS, VA Publication M-610406). The crude model is to demonstrate a triangulation system comparable to an optical cane which Mr. Roth thinks will help solve any mobility problem except those associated with overhanging obstacles. An attachment could be added which would take care of overhanging objects.

Mr. Roth then proceeded to demonstrate his "triangulation only, one range" device. A chopped beam of light is focussed on a surface six feet away from the unit and a second lens-aperture-detector system is adjusted to "see" just the same spot. If there is no reflecting surface, or if the device is not directed so that the design triangulation condition is met there is no signal. If it is met, the user hears a signal resulting from the reflected chopped light. The unit gives its information to the user on the basis of the presence or absence of a signal for given holding and scanning procedures which must be learned. Mr. Roth made an analogy between his device and a cane. A cane has a handle, a shaft, and a tip, the user usually being aware only of the handle and tip. The optical device is the handle, the "shaft" is an optical path through space, and the "tip" is the spot formed on the ground at just the right spot by precise carriage of the projector system, and the return then obtained through the receiving system. The "safe" condition is signalled by a steady sound from the device, loss of this sound meaning either an obstacle or a terrain discontinuity. The user must then test, according to a schedule he has learned during his training period, to determine the nature of the interruption causing loss of signal. Mr. Roth pointed out that his device was a type that had a "holding" problem, i.e. the user had to learn and be capable of rather steady, precision handling of the unit. Persons with other disabilities which might interfere with such performance might not be able to use the device successfully. Professor Benham said to get any sort of feel for the device, the user would have to take it out in unfamiliar territory and travel with it.

Testing in familiar places, often with known obstacles, is far from realistic. Mr. Roth said this is only a demonstration device to check the feasibility of his ideas and is not meant to serve as a finished guidance device. Professor Baumann then spoke about three kinds of people; the inventor with his prototype, the man who takes this and polishes it and makes a beautifully constructed unit of it, and the man who wants to sell the device. He was disappointed that there has been so little communication between those persons in the past. Mr. Roth then mentioned that his device could give the user additional information about the ground surface, picking up things such as checkerboard tiles vs. plain floors. Mr. Freiberger raised the question of the continuous signal from the device, but most present felt this would not be a serious problem. There was then a brief return to the "carrying" problem and Professor Benham said sometimes the good results obtained in a laboratory regarding how stable one can hold a device are not directly applicable to the real-life situation in the street.

Dr. Murphy adjourned the session at 6:00 P.M.

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FRIDAY, OCTOBER 13, 1961
BUSH ROOM

Mr. Howard Freiberger, serving as chairman for this session, introduced the first speaker, Professor Benham, who told of the work at Haverford College. This was begun in 1950 with a Veterans Administration contract to evaluate the Signal Corps Sensory Aid, developed in 1945 by Dr. L. Cranberg, and of which 25 models were made by RCA in 1948. The system of guidance provided by this device looked promising, though there were difficulties with the instrument that had to be overcome. The VA then contracted with Haverford College to make improvements. Professor Benham said his group had been naive in thinking it would take only a few years. The problem of building a satisfactory electronic travel aid for the blind is a most difficult one and has not yet been solved. This project commenced in 1953 and continues to the present. The obstacle detection problem was considered simpler than the curb detection one, so the project was split into two parts: building an improved obstacle detector alone; and working on curb detection. Several things were learned, not the least being that too much information about his environment may confuse a blind person rather than aid him. The selection and rejection of information fed from the tactual or aural end organs is slow compared to the rapid processes associated with the visual system. Even if one could present a large quantity of information to the blind person, the choice of what is presented is very important. Only in rare instances was it found of much value to have the range of a device go beyond ten feet. The current obstacle detectors work on two ranges, about 1 - 5 feet and 2 - 10 feet depending on the setting of a push switch in the pistol-type handle. Professor Benham demonstrated the instrument. It is about 6" high, 7" long and 2" wide. Professor Benham reiterated his feeling that the ear should not be used as the input channel from the device unless there is some very good reason to do so. Much of Haverford's efforts have been devoted to perfecting a tactile system. Stimulators require energy and this puts limitations on design because the unit must be quite portable. The present obstacle device has a small poke-probe which strikes the finger when there is an obstacle. Professor Benham said the stimulator should be silent, first so as not to attract undue attention from others and second so as not to mask the natural sounds so important to the blind traveller.

The obstacle detector is now just about finished and is useful in familiar terrain, but by itself is not a very useful travel aid because it does not detect curbs.

Professor Benham stressed the difficulty of the curb detection problem, pointing out that the only unique thing about a curb was the change in level. Sighted people detect curbs by a variety of cues; change of color, shadows, seeing others step up or down, knowing traffic is passing in a street, etc. They do not generally detect the change in level until they are right at the curb. This is one reason the problem is so difficult for an electronic device. Another is that, try as he may, a person has difficulty holding the unit still enough to make it a good detector of small terrain discontinuities. Arm swing, and vertical and other

body motions when walking complicate the problem. Perhaps the new lamp now being incorporated into the device will so improve the return signal that the motion problem may be eased a bit. The need for comfortable portability also puts severe restraints on the design. The unit should certainly not weigh over 4 pounds and preferably should be lighter. People will not carry a heavier unit for very long.

Professor Benham feels his group is nearing a breakthrough in the curb detection problem. The laboratory model of the curb detector built at Biophysical Electronics weighs about 10 pounds, is about 18 inches high, 12 inches front-to-back, and 4 inches thick, quite unwieldy and unsatisfactory for routine use. The problem is to get this unit down to a reasonable size and weight. The goal is to get one instrument to detect both obstacles and curbs.

Dr. DeVault then told of his work with the curb detection problem mentioning the "hide and seek" idea. The reader may refer to the section covering the Thursday Afternoon Concurrent Session B for a summary of Dr. DeVault's ideas.

Dr. DeVault also described the current effort to build 20-25 improved obstacle detectors. Chopped incandescent light (used in both the Signal Corps and Mr. Roth's devices) represents an inefficient use of energy. It is better to have a short pulse of brilliant light because this method leads to a much better signal-to-noise ratio in the receiving channel. In the present Biophysical device the rather dim, though rich in infra-red, light pulse is 200 microseconds long, probably so designed to accommodate the slow response of the cells available at the time. New cells are faster and will work well with a lamp from E.G. & G. which can give microsecond flashes. It is believed these new components will greatly improve the device, and also serve well in the curb detector unit.

In referring briefly to the stimulator and handle of the obstacle detector, Dr. DeVault showed a mock-up of an improved design with a trigger-like near-far range switch and a redesigned poke-probe.

Covering essentially the same information as he had the day before (Afternoon Session, Concurrent Session B, Bush Room), Mr. Freiberger explained and demonstrated the Franklin Institute cane for somewhat different group forming the joint meeting.

Dr. C. P. Greening of North American Aviation Co., Autonetics Division, Downey, California, then presented a talk on "Extraction of Information from Visual Images." Dr. Greening thought he could contribute most by looking at the problem from the point of view of a designer and manufacturer of systems.

He considers that the mobility problem poses a series of system requirements on any system proffered as a solution. Some of these requirements are:

1. Orientation
   a. geographic, in a compass sense
   b. with respect to the surround

2. Texture of the footing

3. Object management
   a. detection of objects
   b. classification of objects

      I. curb-like (up - down)
      II. wall-like
      III. person-like
      IV. hole-like

   c. capability for tracking object

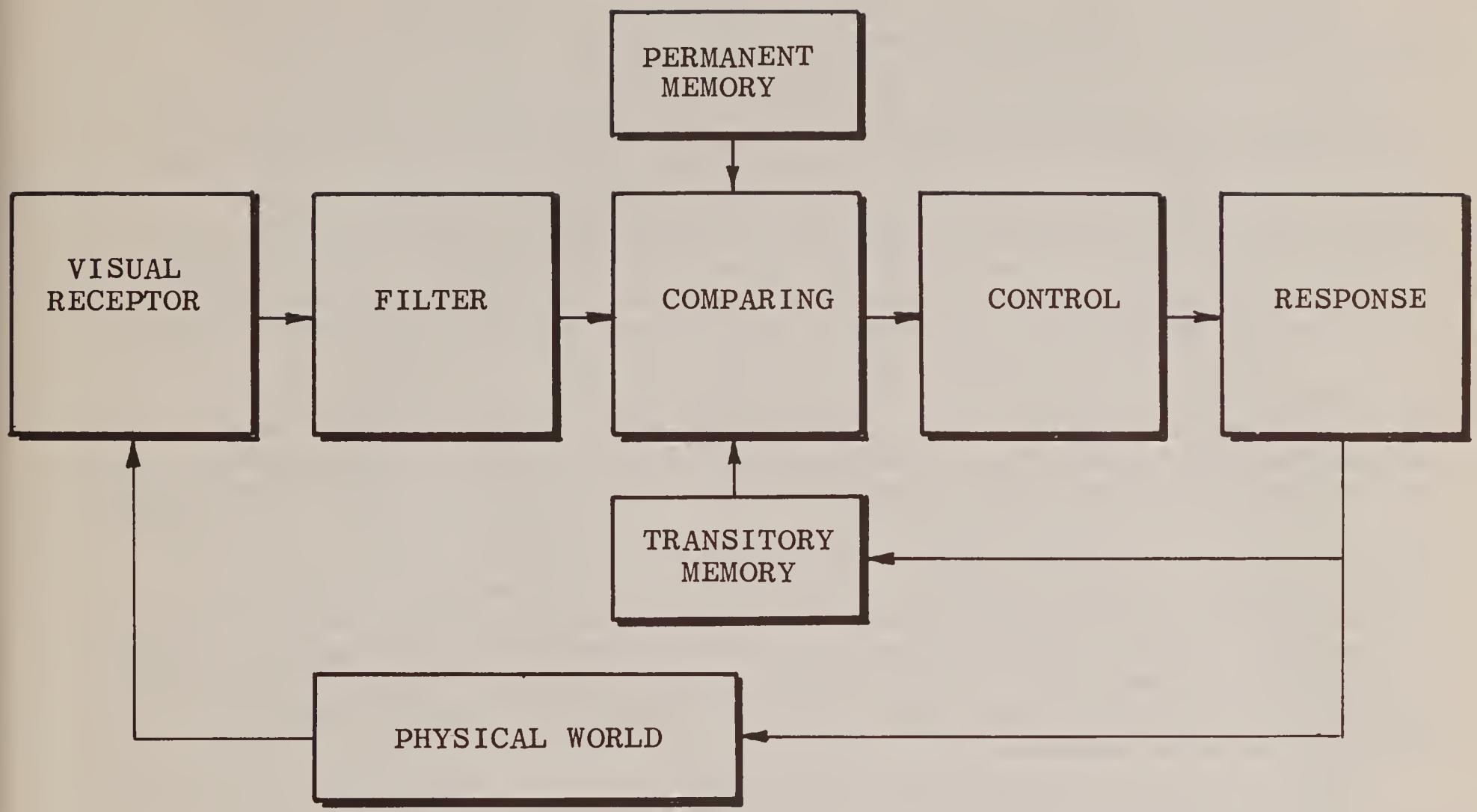
4. Navigation
   a. detection of features or landmarks
   b. classification of the contacts
   c. reference to a map (mental or otherwise)

The similarity between much of this analysis and radar systems engineering should be quite evident. Before proposing any solution, Dr. Greening would pursue an analysis as suggested above, but probably with somewhat greater coverage and detail.

Other areas that require investigation involve the mechanisms, parameters and quantitative analysis of sighted performance of visual tasks and the degradation rates in performance when the visual channel is defective. To design a system it is necessary to know how much and what kinds of information are required to accomplish the tasks in question. The design must then provide for handling the appropriate quantities and types of information.

Dr. Greening then drew a block diagram to further illustrate the systems approach. See Figure 1.

/Editor's note: Captain R. L. Burdick, (MC), USN, of the Air Crew Facilities Laboratory, Navy Air Materiel Center, Philadelphia 12, Pennsylvania, presented a paper "The Failures of Man in a Man-Machine System," November 27, 1961 before a joint IRE - AIEE medical electronics study group in New York. Captain Burdick's paper contains an analysis very similar to Dr. Greening's and includes a very interesting block diagram, Major Pathways in a Man-Machine System./



SYSTEM DIAGRAM OF VISUAL PROCESS

Figure 1

Referring to Figure 1, one first considers the physical world around us. There is potentially a limitless rate of information flow from the world onto the surface of a visual receptor. The receptor certainly has some limitations; it can only see part of the world at one time, can distinguish only between levels of brightness greater than the just noticeable difference, and can recognize only certain things in the field. Some of the "filtering" is physiological. A stabilized image on the retina soon fades away subjectively and edge enhancement effects between areas of differing brightness have long been known. A great deal of filtering is the result of one's years of experience in using the visual system. It has been estimated that the human visual receptor can respond to some 3×10^6 bits/second. We obviously do not use this much information per second, but how much is used to assist in the accomplishment of various tasks is not adequately known. After the information passes the "filter" and we become aware of movements, textures, edges, etc., we do something with it; we compare with a stored permanent memory and also with a more transitory or circulating memory. It should be mentioned that these are functional elements and that the diagram is a functional block diagram. It is not clear that anatomical structures exist which uniquely perform just these functions. It seems the functions are nevertheless carried out, and this is true whether we use the visual system or a substitute for it. Some believe reality is an hallucination, that each of us lives in a kind of hallucinatory world which tends to agree quite closely with the physically real one considering the constant flow of corrections coming to us from the real world. If we are cut off from all sensory imputs our little hallucinatory world tends to diverge from the real world and hallucination become serious.

After comparing with our stored permanent memory and our feelings as to the current status of the world about us, we come out with some status or control information which we use to effect our response. Upon response we get various kinds of feedback to our transitory memory. Proprioceptive information is an example of this. There is also some indirect feedback. For example, if one moves to a new place in the physical world, the information one gets back from it is likely to be changed. It should be noted that these are very hypothetical thoughts, and they may not be germane to the explanation of mobility phenomena. They have helped Dr. Greening in thinking about the problem.

If the visual receptor is deleted from the system, the question is, How do we keep the system functioning? There seem to be at least two or three modes of attack for this problem:

1. Replace the visual receptor. This method does not seem to receive much attention because there is currently no known way to get the vast quantity of information gathered by such receptor into the human system.

2. Replace virtually the entire system. This is essentially what the dog guide system does, the dog having, in some measure, all of the functional components shown in the system diagram.

3. Split the system in some way and substitute devices for various parts of it.

Dr. Greening said he felt that getting a four pound electronic package having all the capabilities of a dog guide is a staggering problem, not likely to be solved in the next decade or so. He also did not think an electronic device having all of the capabilities of the long cane will be realized in the foreseeable future.

The situation is not hopeless, according to Dr. Greening, but some careful systems analysis is required. By this method the number of special aids now required could possibly be cut down. A fully integrated system to provide genuine mobility capability is probably a long way off, so improvement of current specialized devices is a laudable approach.

In reply to a request from Dr. Greening that others present comment, Mr. Zito of Bendix Corporation added he must concur in what had been said. He could foresee no electronic equals of the cane, not to mention the dog guide, within the next decade or so. Professor Benham countered that he felt that an electronic device could improve on the cane in that: 1) it could detect obstacles at longer range allowing the person to take necessary action without coming so close to the object; 2) it could detect curbs at longer range, not requiring the user to have trigger-sharp reflexes to take appropriate and timely action. He further pointed out that not all blind people are capable of using a cane as expertly as Mr. Williams. Reaction time, stumble recovery, and such factors, in many blind people, are not adequate for expert use of the cane. By the electronic device it is hoped reaction time can be "bought" for the ordinary blind person. Professor Benham touched on the danger to research if statements are disseminated to the effect that the cane cannot be improved upon by other devices. Often research funds are choked off when administrators and legislators get the feeling nothing can be done.

Even though it is understood complete system solutions to replace vision are not feasible with the present state of the art, we should try to do something now with what we have, according to Professor Benham.

To further express his viewpoint, Dr. Greening said it was not his intention to suggest arresting development of existing devices in favor of working on his "final solution." He thought in systems terms because that is his usual mode of approach in analyzing a problem.

Mr. Mauch pointed out that his work in prosthetics has made it clear that to help a person with a disability it is not necessary to duplicate nature "one hundred percent," but rather to seek the best available compromise. Professor Benham is trying to help by offering a device that combines features of both the dog guide and the long cane. Artificial limbs have been used for centuries with varying degrees of success, yet if the limb makers had first made detailed systems analyses and then come up with plans to duplicate nature, the venture would almost certainly have failed and no amputee would have received a functional prosthesis.

Dr. Greening indicated he agreed but felt the need for a knowledge of how the visual system is used in mobility, in order to serve as a guide in his thinking. The systems analysis helps in this respect.

Mr. Bledsoe pointed out that expert cane users were most interested in improvements in electronic obstacle detection, particularly with respect to regions not normally explored by the cane. Structures and overhanging protrusions which may strike the chest or head (an awning or shelf) fall in this category. Professor Benham said that with the added power available from the lamps recently tried it may be possible to include such a "high obstacle" detector.

Mr. Dupress said he was firmly convinced that now and in the foreseeable future electronic guidance aids will be successful only as supplements to existing mobility capability which must be developed in an individual by training. The electronic device could serve as a supplement to, not a replacement for, probe-like devices which provide tactile and kinesthetic information.

Professor Gibson asked for some definition of the informational requirements of the mobility process so that he could bring to bear his knowledge of skin communication.

Mr. Dupress replied that one needs to know, with differing degrees of urgency depending upon the circumstances, about:

A. <u>Objects or Obstacles</u>

1. Their identification
2. If two, can one pass between?
3. Are they moving, and if so, where?

B. <u>Changes in the Terrain</u>

Step-ups, step-downs, edges of platforms, stumble-producing irregularities, and the like.

C. Geographic Orientation

To go from point to point one must know where he is to begin with and then use all cues from the environment as he passes through it to aid in reaching his objective.

A brief resume of the informational philosophy guiding the Haverford-Biophysical Electronics group was then given by Dr. DeVault who mentioned that too much information fed to the blind user may not be a good idea. The present obstacle and curb detectors warn the user through tactile stimulation only in the presence of the obstacle or curb; otherwise they are not activated. They could be modified to provide more information, say range to the object, if this were found desirable.

At this point, Mr. Voorhees said he felt ranging information was quite useful, and Professor Benham told of future plans wherein the housing for the electronic devices would be in a cane-like shell. One would have early warning of curbs and obstacles and then approach and explore them using the device as a cane.

An exchange between Professors Gibson and Benham followed in which proper display of multi-bit information was contrasted with the simplicity of dealing with only one or two bits. Professor Benham favored the minimum information input but agreed that for some people, at least, more information could very well prove useful.

Professor Baumann said that the cutaneous information transfer and display experiments should be kept separate, at this time, from the development of hardware. One should not be made dependent on the other as this is likely to impede progress. The sensory experimenter should not wait on the development of devices, but should advance in his area at the same time device work is being done.

Professor Mann raised the question of replacement of the mechanical stimulators in the Haverford and Franklin Institute devices with electric stimulators (electrodes touching the skin). Professor Benham said electrical stimulators require more energy but Professor Gibson took some exception to this noting that sensitivity at different sites on the body varied.

To achieve results in this multi-dimensional work in which we are engaged, Professor Mann said investigators should neither reject completely the work of others nor become so infatuated with it as to lose sight of their own approaches. Attack of the problem on a broad front is necessary, including systems analysis and specific, compromise, hardware projects.

Mr. Bledsoe raised the question of weight of aid devices and referring to the cane said "light cane" would be an appropriate name for the "long cane." Its 7 oz. weight is an advantage as are the few additional inches in length.

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Reconvening after lunch the chairman called on Mr. John K. Dupress to speak on "Human Engineering Factors and Mobility." Unfortunately, Mr. Dupress was unable to deliver his talk due to a case of laryngitis. The following is a copy of his written paper.

DESIGN CRITERIA FOR MOBILITY INSTRUMENTATION
by John K. Dupress

One or more projects in the development of mobility instrumentation has been under way during all but two of the last twenty years. In spite of this effort, no device is currently available nor will any soon be available which will bring mobility to the home-bound or enable cane users to dispense with their canes. Technologists have been overly optimistic in terms of the objectives which could be realized in any program of smaller scale than the present day aero-space efforts. Let us look first at what design criteria these researchers used. The following is a summary gathered from papers written by the principal investigators in these projects: (see bibliography, p.

1) The device should provide more information than is obtained from existing sources.

2) The device should not provide too much information for the individual to process and utilize.

3) The device should not require excessive mental abilities or concentration.

4) The device should not require of the individual any other extraordinary capabilities.

5) It should not require too long a training period.

6) The device should detect all obstacles from ground level to a point above the head in the subject's intended travel path (about two feet wide). It should be capable of detecting objects of ½" diameter at a distance of 7 - 10 feet.

7) Discontinuities in the terrain (step-ups or step-downs) of as little as 2 inches should be detectable at a distance of 5 - 8 feet.

8) The device should have distance discrimination as close as one foot from the detector.

9) Range information should be provided to tell the individual how far away the object is. In recent devices, only two ranges could be selected by the individual. One was approximately 6 - 10 feet, the other, less than 6 feet away.

10) Azimuth information should be provided to tell the individual the direction of the object. Azimuth angles might be divided into increments of 15° right and left of center.

11) If possible, the device should give the individual some pattern information, that is, tell him how the objects are arranged in his intended travel path. It would also be desirable to provide enough data for the individual to identify the object.

12) The time lag between perception of the object by the device and reception of this information by the individual should not exceed one- to two-tenths of a second.

13) The device should not interfere with the normal functioning of the ears as the best receivers of complex information.

14) There was a difference of opinion concerning whether the scanning should be manual or automatic. One researcher believed that at walking speeds of 4 - 5 feet per second, manual scanning was out of the question. Automatic scanning has been deleted from recent devices because of the power factor. It was felt that the individual could use his kinesthetic sensing system to determine the angle at which the object lay.

15) The device should be quiescent except when there are obstacles or terrain discontinuities in its path.

16) The device should be operable under all weather conditions.

17) Although the device should not render the user conspicuous by emitting noise or visible light, on the other hand, it should not be invisible. The person should still be identifiable as a blind person.

18) The device should be attractive in appearance. Blind persons do not wish to carry unsightly equipment.

19) The weight of the device should be less than 4 pounds.

20) The battery life should be at least 4 hours.

21) The device should be simply designed to facilitate maintenance.

22) The device should be rugged enough that if dropped or struck against an object, it will continue to function.

23) The cost of the device and its maintenance should be low enough that the average blind person can afford to purchase and maintain it.

24) The device should be relatively simple, like a hearing aid or camera, so that the individual does not have to "dress up" in it.

25) The device should be simple to put into operation. It should involve no more than turning a knob or throwing a switch.

26) For female users, there should be a guard to prevent skirts and overcoats from obscuring the view of the device.

Considering both our past experience and the current state of technology, I suggest we add a few criteria to those above and modify some of those that appear on the list as follows:

1) No device being developed or contemplated for the near future can detect all of the objects which might cause injury to the blind traveler. It is realistic, therefore, to continue using the cane and add extra information. Since an excessive amount of energy would be required to automatically scan the area from ground level to a point above the head in a two-foot-wide path, the obstacle detector should therefore concentrate on the path through which the subject's head travels. If the device is

energy-radiating, the emitting and receiving units can be miniaturized and head-mounted as though they were glasses or binaural hearing aids. The remaining problems would continue to be handled by the cane. A second possible place for mounting the emitting and receiving units is on the cane itself. Early warning of head-level objects at 7 - 10 feet would be desirable.

2) Discontinuities in the terrain should also be detected 7 - 10 feet ahead. The 2" minimum set by a previous research project is a reasonable one. It is unlikely that any step-down detector will provide the precise information required for individuals to step up or step down. This will still have to be done by the extension of his cutaneous-kinesthetic system which exists in the cane. A step-down detector would probably function better if cane-mounted.

3) Both of these devices should be light-weight and miniaturized. Reasonable goals are: less than 6 ounces weight; less than 50 cubic inches total volume for electronics and battery supply. Emitting and receiving units can be less than 2 cubic inches in size for head-mounting.

4) The battery problem has been pretty much solved with such developments as rechargeable nickel cadmium cells, which provide a surprising amount of power in a small space and weight. The power consumption of the devices should be low enough that the batteries do not have to be recharged until the device has been in operation for at least 4 hours.

5) Although the device should be quiescent when there is no object in view nor any discontinuity in the terrain, there must be a fail-safe provision to notify the user when the device is malfunctioning.

6) The device must be reliable. The problem with devices so far has been that they have not continued to work properly even for the relatively short periods required for evaluation.

7) Although it is not possible to set a ceiling on the maximum price or the operating cost, a unit costing several hundred or two or three thousand dollars would have to be as useful as a guide dog. By the same token, very few blind people could afford a unit whose operating cost was several dollars per day, or even several dollars per week, for that matter. If the unit is not going to make a substantial contribution in enabling the person to travel faster, more efficiently, and more safely than he can with a cane, the device cannot be sold for any substantial sum.

In the final analysis, it will be difficult to build a device which improves upon the use of the cane by a person who has had good mobility training. This does not mean that we should discontinue research on mobility devices. There are, however, two cautions which must be exercised in evaluating these devices:

1) The experimental design for the evaluation must be carefully conceived. There must be a period of time in which to try out the experimental design. In other words, research on the experimental design for the evaluation is required.

2) It is necessary to devise an adequate training program. Mobility is a complex task which requires weeks of training in the use of the cane. There is no reason to expect that a somewhat more complicated device than a tactile probe will not require a fairly extensive training period. It is wise to assume that it will take at least several months to devise an adequate training program for the use of a mobility device.

When these two factors are carefully considered, only then will we be in a position to give a device a reasonable and accurate evaluation.

The mobility problem for blind people will be solved in the somewhat distant future in much the same way that direct access to the printed word and graphic forms will be solved. We must build an electronic version of some lower order visual systems which can then be connected to a man in such a way that he can have what amounts to crude visual sensation. Whether this device is tied directly to the central nervous system remains to be seen. Whether the coding is such that the individual can learn to recognize complex patterns is also a matter for speculation. Bio-medical electronics research can certainly improve, however, upon the narrow tunnel vision which is available through past and present mobility devices. If the human being with his brain and large storage of visual data cannot operate in the mobility situation with a wide angle tunnel vision, you can assume that he will have more difficulty with a narrow-beam probe device. The probe device is simply the first in a series of steps. Some people will be able to use these probe devices, others will be able to utilize more complex equipment. This means that we will have a family of devices over the decades which will, along with mobility training, eventually solve the problems of those blind persons who wish to travel.

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Professor Sheridan inquired of Professor Benham as to the advantages of a five-foot range electromagnetic-energy probing device over a five-foot long cane. Professor Benham mentioned the clumsiness of such a long probe, problems of storing it (unless a really satisfactory telescoping unit could be developed), chance of tripping or otherwise hindering passersby.

Professor Mann then questioned the workers for the blind as to the need for, and value of, some identifying mark that a person is blind and thus entitled to certain helps and immunities from the sighted community. Mr. Holopigian remarked that this question of identification is quite controversial with probably as many answers as people who answer.

Mr. Voorhees felt it was premature to consider cosmetic factors at this time. A blind person, using devices of the kind mentioned today or those coming in the foreseeable future, could be identified by his behavior rather than by what he is carrying, whether concealed or not.

Messrs. Bledsoe, Apple and Suterko also addressed themselves to questions of the cane, its size, color and techniques for use. Mr. Suterko told how a long cane may be used fully extended for rapid walking in uncongested areas, and how it may be shortened in congested areas where the usual pace of all persons is often slower and where the shortened cane presents less risk of tripping others. Mr. Suterko made a plea for improved cane design emphasizing that attention should be given to the tip. An ideal tip would be so shaped as to minimize the chances of its catching and "sticking" in cracks, grass, etc., would be very resistant to wear, and would not reduce the flow of information up the shank resulting from the cane touching the ground or some object.

The chairman noted that matters of cane design and suitability kept coming up time and again during the meeting. Improvements in the tip and in mechanisms for folding or telescoping to allow compact handling and stowage in certain circumstances received most emphasis. He then asked the engineering contingent present for comments on the design of improved telescoping canes. Professor Mann asked what the requisites of a good cane were, and Professor Baumann said he had already begun to collect such data.

The question was then raised of the economic disparity between canes and electronic devices and whether there was something more in the argument for electronic devices than just the anti-tripping element. Professor Benham replied that there was, that probing space for obstacles using the hands or long probes is quite unpleasant for many, and that the unobtrusiveness of the electro-optical method would be welcomed. Mr. Bledsoe said he feels that blind people, and especially deaf-blind people, should be encouraged to touch things and that the more they practice this art the more graceful they will become.

Professor Gibson asked Mr. Apple if he could tell the group what a "good" cane is. Mr. Apple said it should be light in weight (his weighs 11oz.), about 1/2" diameter in the shank, tailored in length to the individual (his is 52"), have a tip that would not catch or stick on surfaces (he has a 2-2½" maple dowel as a tip on his cane), have the center of gravity 2/3 the way up the length. A grip is needed for comfort and to take care of thermal effects when the cane may be very cold. A modified golf club grip is used in some instances.

Professor Baumann asked for comment on collapsible canes and Mr. Voorhees showed a collapsible model he carried. He found the principle of telescoping or collapsibility excellent, but available embodiments never perfectly satisfactory. The canes did not seem to have the rigidity of the unitary design, and because of wear in the joints they soon lost what rigidity they had initially.

Miss Baird commented that it is not so important to keep the cost of a really good cane down to two or three dollars. Other widely used devices such as braille writers, transistor radios, hearing aids, and eye glasses can exceed one hundred dollars in cost. Collapsible canes are much in demand by blind women and teen-age girls who appreciate being able to put the cane into their pocketbook when not needed. These collapsible canes, unfortunately, have not been rigid enough and are subject to more frequent breakage than their solid counterparts.

Some discussion of Fiberglas shanks followed. Mr. Suterko said that the whiplash in the solid units he had used was a disadvantage and Mr. Voorhees said he found the hollow Fiberglas shaft (as in the Franklin Institute cane but with an ordinary handle) quite sensitive and extremely light.

In a brief discussion on cane tips Professor Mann mentioned possible use of a plastic such as nylon or teflon in place of maple as the tip insert. Mr. Freiberger said he sensed an informational compromise situation between not touching the ground at all, not sticking, and getting no contact information, and on the other hand, touching heavily, raising the chances of sticking, but getting maximum contact information.

The chairman then asked for discussion of the problem of evaluating mobility devices. Professor Mann, with concurrence from the group, noted that evaluation was an important aspect of the subject. His attendance at these meetings suggests to him that different specialist groups have evaluated the several devices available in the past, usually the ones most familiar to them, but that no single group, at the same time experienced and unbiased, has ever undertaken a thorough comparative evaluation of the various units.

Mr. Bledsoe said the evaluator would have to be an expert in evaluating prejudice, and also that a careful eye examination is most necessary. Many earlier "scientific" studies have been marred when it was discovered that no one was quite sure what the subjects did or did not see. Many conscious and unconscious cues are available to the partially sighted traveller and such things must be given careful attention in any evaluation study.

Mr. Upshaw said many persons had some residual vision and that progress is being made with low vision aids. He said some scale of visual efficiency rather than visual acuity should be used. Acuity only measures one of several factors entering into use of partial vision in mobility. Persons with 20/200 vision travel more or less as sighted persons do. They see traffic lights even during the day, can read elevator indicators, have little difficulty with curbs or steps. When the acuity is only 10/200 however, the individual has trouble with most items mentioned above. In any evaluation program the techniques should be evaluated as well as the devices. A technique good for a man with 20/200 vision may not be suitable for a man with only 10/200. For example, optimum use of the long cane by groups having differing visual efficiencies will call for different techniques.

Mr. Bledsoe commented that current measures of visual efficiency are not precisely indicative of a person's visual capability, and that the selecting of subjects for evaluation of devices must take this into account. It would be best to compare totally blind persons with totally blind persons in evaluating a technique or device rather than totally blind with those with a little bit of sight.

Dr. Graham said that evaluation has two elements: 1) engineering evaluation (by an impartial arbiter); 2) field testing (developmental work, separate and distinct from research effort). There is no agency doing systematic work in either of these areas for our field of interest at the present time. Professor Mann concurred with Dr. Graham pointing out that a device must be engineered to the point where it is physically reliable and has satisfied the design specifications. The problems of relating the man to the machine are undoubtedly the more difficult. Professor Mann pointed out that we have generations of experience with some aids for the blind like canes or dogs and that the training programs used with these aids have evolved over many years of observation. No such background exists with new devices and the training program often must be developed at the time the evaluation is in progress. Thus, there is risk of incorrect evaluation; is the device bad because it is intrinsically bad, or only because the training program used with it is inadequate?

There was a 15 minute recess and on reopening the session, the chairman outlined plans for deriving permanent benefit from these sessions. A committee is to be appointed by Mr. Dupress to come up with plans for the future based on these deliberations. A set of minutes of the conference will also be prepared and distributed to all participants. The chairman noted that the consensus of the group seems to be that work should be carried on in all areas; new shafts and tips for canes, optical and electronic aids, even possibly developing breeds of dogs to serve as dog guides.

Dr. Graham suggested the committee might consider:

1. The need for a systematic developmental effort as well as a systematic research effort in mobility aids. The development phase should involve psychologists because of the human beings using the aids.

2. Just what information about the human is required by the engineers so they can best design instruments to do the job of providing mobility aid. The behavioral scientists should supply this information.

There should be a coordinated program, according to Dr. Graham. He mentioned that the American Foundation for the Blind has excellent facilities to do this coordination. American Printing House for the Blind and Perkins School for the Blind were also mentioned, and Dr. Graham said coordination between these three institutions and perhaps others was necessary. He made a plea to those present who had control of research funds not to fund isolated and separate projects, but rather a large coordinated program, funded as a program, with some central responsibility for carrying it through to the end. Thus the committee should:

3. Consider the program approach to mobility research rather than the individual project method.

Mr. Apple also suggested that the committee consider hearing aids which maintain their performance at frequencies of 4000 cps and up even after moderate discharge of their batteries. He also raised the question of the vaulue of binaural hearing aids to blind persons saying he desired information on this subject.

Good rapport between the practitioner at the field trial level and the scientist in the laboratory should be maintained by some practical system according to Mr. Bledsoe.

Professor Sheridan, returning to the question of hearing, said low frequency pure tones tend to mask high frequencies more than highs tend to mask lows. He then postulated that the spectral characteristic of the human ear is probably adjusted to the sounds a sighted person is likely to hear and that a blind person might require a totally different response curve for most efficient handling of the sounds he uses. Maybe the low frequencies should be attenuated and the highs amplified, or filters of various characteristics could be interposed.

After a few concluding remarks, the chairman extended thanks to all for their participation, and then adjourned the conference.

APPENDIX A
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APPENDIX B

PROSPECTUS FOR MOBILITY RESEARCH*

The subjects listed below represent the majority of items suitable for a mobility research plan. There is a continuum from basic research through programs and services.

For purposes of preparing this outline, there are several major groupings of subjects. This results in a relatively neat presentation which is not necessarily realistic in terms of actual research projects. It should be assumed that good research projects may combine two or more specific subject areas or may deal with sub-divisions of subjects.

I. MOBILITY CAPABILITY (With and Without Formal Training)

1. Compilation of data, analysis and preparation of document on mobility capability without formalized training.

2. Compilation of data, analysis and preparation of document on mobility capability with training at rehabilitation centers, (cane travel and dog guides) residential schools, itinerant mobility instructors, and through the home teachers services. The final document will include summary and recommendations concerning common elements in these mobility rehabilitation programs and services which seem to be of proved value based upon past experience.

3. A study of the deterioration in mobility capability over the years and subsequent thereto, initiation of suitable "refresher" mobility training.

II. MOBILITY CAPABILITY WITH RESIDUAL VISION

1. Review, analysis and preparation of special documents which attempt to define the conditions under which independent travel is possible with residual vision. In the summary and conclusions of such a document, specific recommendations for survey and other research would be included.

2. In conjunction with the Visual Impairments Sub-Committee of the Rehabilitation Codes and other interested organizations, as well as individual ophthalmologists, researchers in the area of vision, etc., specific recommendations for research to improve measurement of the partially sighted would be outlined. This would include such items as the contrast conditions obtaining during measurement, eye and head movements, color perception, peripheral field acuity and dynamic as well as static conditions. Additional items will appear as research proceeds.

* This Prospectus will be revised and included as part of a document which will represent a long-range mobility research plan.

3. A review and analysis of low vision instrumentation prior to detailed recommendations for the development of additional needed aids. Research on light amplifiers could then proceed against a background of information acquired in both the mobility and reading areas.

4. The effects of visual masking in training the partially sighted would be included.

5. A study of the interaction of low vision aids and mobility training with a view towards optimizing the successful use of low vision aids for mobility in the context of applied research during training.

III. FACTORS IN MOBILITY CAPABILITY

1. An engineering systems analysis of information acquisition with a cane is underway in the Engineering Projects Laboratory of the Massachusetts Institute of Technology.

2. Although the dog guide is a useful mobility device for a small portion of the blind population, a fruitful area for investigation is an analysis of the interaction of man and dog with a view towards providing characteristics for the breeding of dogs for an aging blind population, or for those individuals who seem psychologically and/or physically incapable of being mobile with a cane or with a working dog. In addition, more research is required on all the factors which are relevant to the man-dog interaction.

3. The three main sub-divisions in mobility task performance are navigation, obstacle detection and the detection of terrain changes (step-ups and step-downs). In outlining research which covers these areas, we are dealing with the psychological aspects, the use of binaural hearing, the cutaneous and kinesthetic senses, memory, individual intelligence and a variety of other factors interacting to produce varying amounts of capability or a substantial inability to travel independently.

4. In order to bring together data in the psychological area, a very important step is a review and analysis of existing psychological and sensory tests for the sighted as well as the visually deprived.

5. A compilation and analysis of existing sensory measurement devices and tests should be made with particular reference to low residual vision, the parameters for determining binaural hearing efficiency, impaired and normal hearing, the tactile and kinesthetic senses, reflex actions and any other items which may appear in the final document.

6. Obstacle sensing with binaural hearing began to be investigated with the work of Dallenbach, Worchel and others. They investigated only in a limited way a few factors. A list of the variables which occur are as follows:

(a) The size, shape and materials of the objects
(b) The determination of multiple as well as single objects
(c) The stationary as well as moving subjects
(d) The composition and level of ambient noise
(e) The acoustical properties of enclosed areas
(f) Sound generating as well as silent objects
(g) The effects of sun, wind, humidity and other atmospheric conditions.
(h) The interaction of muscle sensing with binaural hearing and head movement.

All of these variables need to be studied in basic research projects. In the meantime, some initial data will be gathered in conjunction with the C. W. Shilling Auditory Research Center in Groton, Connecticut.

7. Research on navigation must be undertaken. The use of tactile materials, the ability to develop mental constructs of an area, muscle memory and other items which contribute to successful navigation without visual input constitute one or more projects. When blind persons leave bounded paths, some kind of navigation devices must be developed to enable them to follow a straight line, determine changes in direction and integrate the total path to achieve a travel objective.

8. Although research has been conducted for nearly two decades on active radiating mobility devices, prototypes which are sufficiently rugged and otherwise reliable must be put into the hands of blind subjects, experimental psychologists and rehabilitation specialists operating as a team.

9. Research on passive or ambient devices should be resumed.

10. Basic research is required on selectively extracting data from what would be a normal human visual field. In this way, researchers would have some idea of how much visual data is minimum to certain task performances utilizing the human computer to obtain a more effective man-machine operation. Basic research on both the end organs and the brain interacting must be correlated with the visual processing research.

11. Although some initial evidence has been obtained by the New York School of Social Work, the social scientists should provide a careful analysis of the role of motivation in mobility capability. Many other psychological as well as sociological factors should also be studied.

12. In addition to research on the information acquisition through binaural hearing and the cutaneous and kinesthetic senses, research is required on other sensory processes (thermal sensing, changes in humidity, olfactory sensing, etc.).

IV. MOBILITY BY LIVING CREATURES OTHER THAN MAN

1. A compilation and analysis of current research in animals, birds, fish and insects which move successfully through a complex environment with little or no vision should contribute to the design of better instrumentation for man as well as the understanding of certain techniques which might be applied to mobility training.

2. Certain instrumentation can be built based upon data already available. For example, one elementary prototype which takes advantage of lower mammal and insect vision was designed last year to measure color. The output could be read tactually or through changes in an auditory output.

V. RESEARCH ON MOBILITY DEVICES

1. A review of past and present research on active and passive mobility devices with some attempts to evaluate their worth constitutes one subject area.

2. A compilation of data, analysis and the preparation of a document on human engineering or human factors research which is relevant to mobility devices and which represents man-machine interactions.

VI. PRODUCT ENGINEERING AND EVALUATION

1. The laboratory prototypes of devices must be product engineered. Research and development are concepts which belong together, and they must be planned to occur before any device will be available in quantities to blind persons.

2. Evaluation criteria must be established which in turn, requires research on: (a) experimental design to determine the effective man-machine interaction; (b) training procedures to develop skill in the use of the device; (c) precise definition of evaluation objectives against the rehabilitation background.

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